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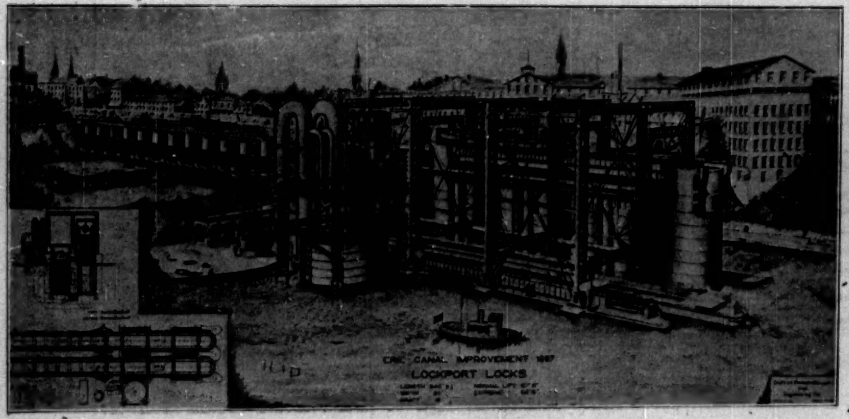
THE DUTTON PNEUMATIC BALANCE LOCKS FOR CANALS.*

BY CHAUNCEY N. DUTTON, NEW YORK,
Member of the Institute.

These locks float on compressed air confined in their lower open-bottomed air chambers, whence it displaces water. Each lock carries a gated tank containing sufficient water to float the boats. When one lock descends the other ascends, the descending lock expelling air from its air chamber into the

* An address delivered before the Franklin Institute, Philadelphia, November 16, 1897, on the "Pneumatic Balance Locks," approved by the State Engineer and adopted by the Canal Board of the State of New York, to replace five pairs of lift locks at Lockport, and two pairs of guard locks between Lockport and Buffalo; and sixteen pairs of lift locks, known as "The Sixteens," at Cohoes, on the Erie Canal, in New York State. Revised by the author for publication.


ERIE CANAL IMPROVEMENT 1917
LOCKPORT LOCKS

air chamber of the ascending lock through a 13-foot, valve-controlled connecting type. No compressed air is discharged into the atmosphere or wasted. The moving force is an excess of weight in the descending lock, in which the draft of water is 1 foot greater, such "surcharge" being 330 tons. The greatest energy-rate is 1,150 horse-power; the average, 115 to 150 horse-power.

At Cohoes, the lift is 144 feet. At Lockport the normal lift is 57 feet 5 inches, and the extreme lift, when floods raise the upper level, 62 feet 5 inches. The least draft is 12 feet; the width, 28 feet at the bottom and 30 feet at the top; the clear or effective length, 310 feet.

They will pass up-stream two boats drawing 12½ feet and carrying each 1,350 tons, or 2,700 tons of cargo per lockage; and down-stream two boats drawing 13½ feet and each carrying 1,450 tons, or 2,900 tons of cargo per lockage.

They will make their stroke in one minute, and, allowing for entry and exit, are expected to detain boats eight to ten minutes.

The locks are built of steel.

Each has an upper, gated lock chamber, and a lower, open-bottomed air chamber containing compressed air, on which it floats, and as the volume of its air-charge is varied, moves up and down in a pit or deepened portion of the lower level of the two which they connect.

The locks are kept from tilting sidewise by guides, and from pitching endwise by an automatic leveling apparatus, consisting in fixed racks, anchored to terra firma; parallel racks built on the locks, and hollow built-up shafts armed with pinions, which mesh with the opposite parallel racks, on which they hang, without other bearings, and between which they roll when the lock moves.

The air chambers are so proportioned that they automatically differentiate the air pressure, so that the lock which descends forces the elevated lock up against its anchors with an effort exceeding by one-third the weight of said lock and its load, so that it may be connected with the upper level, and used in the roughest manner with entire safety.

The devices to retain the elevated lock against the unbalanced hydrostatic pressure, and the gates and other parts which are liable to ramming, will sustain ramming by boats going 3 miles per hour.

If injured boats sink in a lock, it can be used as a dry-dock.

The locks can be raised clear of the water for painting and repairs.

At Lockport each lock weighs 1,500 tons, and will contain over 4,500 tons of water. The weight in motion exceeds 12,000 tons.

The first locks at Lockport, opened in 1825, passed boats 3 feet 5 inches draft, 14 feet 5 inches wide, 78 feet 8 inches long, carrying 80 tons. They were replaced about 1838 by the present stone locks, which pass boats 6 feet draft, 17½ feet wide, 98 feet long, carrying 250 tons. These locks are in a remarkable state of preservation for old limestone masonry exposed to our northern winters. The stone shows little decrepitation, and most of the joints are still tight, showing that the cement was good.

About 1880 the system of towing double-headers was introduced on the Erie Canal, from the Illinois and Michigan Canal. In this system two lashed boats form a towing unit, the stem of the rear boat being pivoted on the stern of the forward boat, and the lashings carried around pulleys and a capstan, by which the rear boat can be swung like a rudder 98 feet long. Two or three such units are towed in a fleet of four to six boats. The cheapness of the system induced the State of New York to adopt, in 1885, the policy of lengthening the Erie Canal locks, so that the two boats could enter without being uncoupled. Forty-one locks have been lengthened; but the five locks at Lockport, three at Newark, four at Little Falls and eighteen between Cohoes and tide water have not been lengthened, their location making it impractical. When the late State Engineer, the Hon. Campbell W. Adams, and his deputy, Herschell Roberts, C.E., took office, in 1894, they grappled with the problem to lengthen the unlengthened locks, or to find a suitable substitute for them. They examined the hydraulic and other types of mechanical lift locks

then in use, decided that no one of them was adaptable to Erie Canal dimensions and traffic and commenced studies of the problem, which finally led to the adoption of the pneumatic lock.

The 1895 session of the New York State Legislature passed a bill appropriating $100,000 for the construction of mechanical lift locks at Lockport; and another, $77,500, for similar locks to replace locks 21 and 22, near Schenectady.

The Governor vetoed the Lockport appropriation, the appropriation for the lock near Schenectady was deemed insufficient, and no work was done at that time on either. The same Legislature referred to the popular vote, an act authorizing a credit for $9,000,000 for improvement of the State canals, which was adopted by a large majority at the November election. Within the month State Engineer Adams ordered the preparation of three sets of plans for mechanical lift locks at Lockport. In his report for 1896, p. 25, he says:

"Three sets of plans for this work have been developed, and one of the conditions which all have been designed to meet is that the adopted plan should be capable of economic installation either at Lockport, Newark, Little Falls, or Cohoes. Two of these plans provided for suspending the lifting troughs by cables, and operating the same by two distinct hydraulic methods, but on the completion of the estimates the cost of either of these plans was found to be too excessive to warrant their adoption. The other plan, which has been adopted, depends upon compressed air for its operations. Owing to the probability that several important features in this plan will be considerably changed before the work is advertised for letting, I do not deem it advisable at this time to go into any detailed description of the plans and method of operating, but prefer to leave the subject until the next annual report, in order that it may then be carefully and fully discussed and illustrated. The adopted plans have been prepared by Chauncey N. Dutton, C.E."

The new locks were to be located to one side and in advance of the existing locks, so that they could be completed and put in operation without stopping the use of the old ones. This called for considerable extra expense and the construction of a steel aqueduct, 393 feet long, to connect the locks with the upper level.

These are the only locks between Lake Erie and Rochester, and it was, therefore, deemed advisable to make them of such size that they would give Rochester practically as good a connection with Lake Erie as Lake Ontario ports

have through the Welland Canal. The scale was, therefore, enlarged from 6 x 17½ x 98 feet to 12 x 24 x 240½ feet. This scale has been again enlarged by the Advisory Commission on Canals of New York State to 28 feet clear width at the bottom and 30 feet at the top of lock chambers, with a net or effective length of 310 feet. When the locks are installed, boats can voyage between Lake Erie and Rochester more quickly and cheaply than between Lake Erie and Lake Ontario ports *via* the Welland Canal. It is expected to build up a large trade in transit between the Susquehanna Valley, in Pennsylvania, and the Great Lakes, at a considerable reduction on present freight costs.

The detention at the present locks is frequently several hours, and never less than one hour, because the fleets have to be broken up. The new locks will pass double-headers in eight to ten minutes.

The present stone locks cost $698,000. The first estimate for the steel locks, made in December, 1896, was $576,000, but when the completed plans were adopted by the Canal Board, June 24, 1897, the estimate was put at $499,000. The market prices of steel and machinery fell sharply in the interim, but have now advanced, and when the enlarged locks are put under contract, which will be when the Legislature makes appropriation for them, the work will cost about $1,000,000. The Cohoes locks will cost one-half more.

It will be seen that the new locks at Lockport will cost about one and five-eighths the cost of the stone locks. They will handle units twelve times as large in one-sixth of the time. The dollar invested in them has, therefore, more than forty-four times the earning power of the dollar invested in stone locks.

The characteristic features of the locks may be described briefly as follows:

(1) Compressed air is substituted for water as the element of translation and support of the locks and vessels. Increasing the height of lift does not increase the pressures, and, therefore, locks of any height are practicable and much cheaper in first cost and in operation than a flight of low lift locks.

(2) The working pressures are very much reduced, the maximum being about one and one-half times the draft.

(3) The motion of translation is uniform, having no tendency to accelerate, being regulated by the velocity at which air can pass through the conduits with the given head.

(4) The locks have absolute immunity from falling. The pneumatic lock falls up, if it falls at all. It is pressed up firmly against the anchors with an effort much greater than the weight of the lock and its load. If the anchors yield, the lock is forced up to a height such that the air in the air chamber is expanded to equilibrium with the load, and a volume of water equal in weight to the difference between the load and its initial excess of buoyancy enters the air chamber.

(5) The speed can be very great, because air flows at high velocity with a slight head.

(6) Working the locks in balance, by slight differences in weight, saving 95 per cent. of the water heretofore used, and avoiding heavy currents in the canal sections.

(7) The water-trap valve for controlling the air conduit.

(8) The powerful automatic leveling, or synchronizing gearing, of construction cheap, such that the price per pound does not increase with increased power.

(9) Dispensing with the dry-dock necessary in other types of lift lock and operating the locks directly in the lower level of the canal, in a pit; the pit in which the locks work being part of the lower level.

(10) The substitution of steel, mainly in tension, for masonry in the lock structures.

(11) The substitution of elastic resistance for mere stability due to dead weight, and the consequent reduction of strains due to shock, so that they can be taken care of economically.

The principal elements of design are:

(1) The locks, which float and work in a pit formed in the lower level, and are identical structures, each having an upper gated lock chamber for the vessels and water to float them, and a lower open-bottomed air chamber containing the compressed air on which they float.

(2) Valve-controlled air conduits for transferring air from one lock to the other during translation.

(3) Anchorages to restrain the superbuoyant elevated locks.

(4) Guiding structures to prevent the locks from tilting sidewise.

(5) Automatic leveling, parallel motion, or synchronizing apparatus, to keep them from pitching endwise.

(6) A pneumatic accumulator, which is connected with the elevated lock and maintains a constant working pressure therein, automatically compensating for changes in density and temperature of the adjacent atmosphere.

There are other important elements connected with the locks, which, while desirable, are not absolutely essential, namely:

(7) Hydraulic stops and accumulator-intensifier, by which the elevated lock can be perfectly controlled and adjusted in position.

(8) An interlocker, or sequence machine, which orders the operations incident to the motion of the locks, by means of valve-controlled compressed air transmissions.

(9) Automatic stop machines, one geared to each lock, adjustable to varying water levels, which prevent the locks from running away and automatically control the variations in depth of water when elevated.

A recital of the difficulties will aid in forming a clear conception of the motive and functions. A lock is the heaviest of engineering structures, carries per square foot a load greater than the load per running foot of the heaviest railroad bridge, and is subject to tremendous and cumulative distorting forces, which necessitates that the structure be of simple type and extreme power, and automatically leveled and controlled by apparatus strong enough to beyond peradventure arrest distorting forces in their incipiency and annul their cumulative tendency.

The locks are liable to be bumped and rammed and to have boats carry away the outboard gate and sink with the boat's nose overhanging the end of the lock. A boat in this position,

half the length of the lock, or a boat of said length sunk in one end of the lock, would overload that end with a weight equal to the weight of the boat and cargo. The leveling, or synchronizing apparatus, must be powerful enough to sustain this distorting effort and distribute it, and, furthermore, it must be automatic, for were the least interval of time to intervene between the application of the distorting forces and the action of the leveling apparatus, the loaded end would pitch, the water would run off the opposite end and pile up in the loaded end, giving a cumulative effect, combined with shock, which must inevitably destroy any non-automatic apparatus, how strong soever it might be, and ruin the lock.

DESCRIPTION OF THE LOCK STRUCTURES.

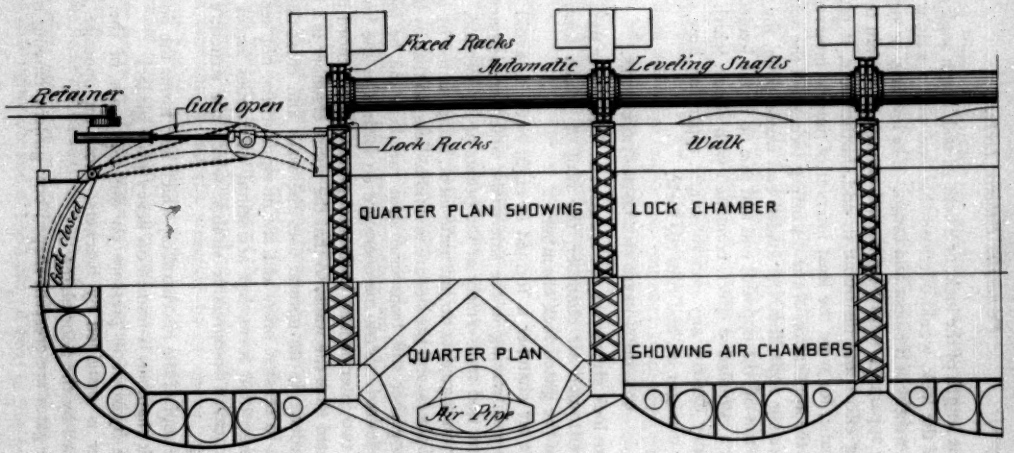
The lock structures are identical. The lower part is an open-bottomed air chamber, the roof of which forms the floor of the gated lock chamber.

The air chamber is formed in eight bays, to avoid beam strains and framing in the side walls, which are segments of cylinders tied transversely at the points of intersection. The cylindrical segments do not quite meet, being united by longitudinal plates, and the ties are in double lines, so that by lacing them together stiff transverse strut members can be formed where desired. Strut members are so formed at the bottom and at two intermediate horizontal planes, where chord plates are united with the walls, so that the entire chamber is a huge box girder. In its normal uses the walls and cross-ties are subject to tension only, and are in equilibrium, not tending to change their form, but accidental extraneous forces may tend to cause compressive strains, which the structure will sustain.

The roof of the air chamber, which also forms the floor of the lock chamber, is framed on heavy plate girders.

The hydrostatic pressure on the side walls of the lock chamber is sustained by brackets; those on opposite sides being tied by the floor plates.

The gates are crescent-shaped box girders, moving orbit-


Fixed Racks
Automatic
Leveling Shafts
Retainer
Gate open
Lock Racks
Walk
Gate closed
QUARTER PLAN SHOWING
LOCK CHAMBER
QUARTER PLAN
SHOWING AIR CHAMBERS
Air Pipe

ally on a wheel, and when open lie out of the way in segmental side pockets.

The seating faces are concentric with the vertical axes about which the gates move orbitally.

The gate-opening engines have each a cylinder 14 inches bore, 8 feet stroke, the piston moved by compressed air, the piston rod carrying a cut steel rack, 4 inches pitch, 7 inches face, which meshes with and turns a pinion keyed to one end of a shaft, on the other end of which is a sprocket wheel geared by a Yale & Towne $\frac{3}{16}$ inch chain to a sprocket wheel on a vertical shaft, secured in bearings on the gate post. This driving shaft has spur pinions at top and bottom, which mesh with pin-wheel segments on the gate. When the piston moves, the connected rack turns the shafts and pinions and operates the gate.

The gate is lightened by a flotation chamber, which floats 74 per cent. of its weight, leaving 26 per cent. on the wheel to give stability. The air which fills the flotation chamber is constantly renewed, so that the gate will not get logy.

The gates which are liable to be rammed contain elastic trusses, with a yield of 10 inches, which cushion the blow and deliver it to the gate posts, so that ramming has no effect on the gate itself until the elastic trusses are broken.

The gate openings are slightly wider than the locks, so that the jambs are not liable to ramming, being protected by the guard timbering on the lock walls, which is as elastic as possible, to that end being supported in the centers of the plates on rubber cushions, so that the effect of impact is distributed over a number of brackets and lessened by the elasticity of the guard timbering, its rubber supports and the plates.

When the lock is elevated, as aforesaid, it is superbuoyant, having an excess lift exceeding the accidental increase of load which might occur through the sinking of a loaded boat, and this excess lift is restrained by anchors, which are steel plates secured to the bed rock, and encased in asphaltic concrete piers. On them are built the side guides and the fixed racks of the leveling apparatus. These are disposed

in four transverse lines at the end and alternate intermediate intersections of the bays.

When the ascending lock comes to rest, its momentum is absorbed without shock, by hydraulic stops swiveled on the anchorages, with which the elevated lock engages, by brackets armed with timber contact pieces, which are readily movable, to allow the lock to be raised clear of the water for painting and repairs.

AUTOMATIC LEVELING, OR SYNCHRONIZING APPARATUS.

During the years which have been devoted to developing the pneumatic lock, many different types of leveling apparatus were considered and more or less worked out, but were all prohibitive in cost, especially on a large scale. The characteristic features of that adopted are that it is always in action; has only rolling friction, normally sustains only its own weight, has the minimum wear and abundant end clearance, which prevents binding and temperature strains. It can be made of any power, and the larger it is made, the less will be its cost per pound. It does not require nice workmanship, or careful adjustment. It is what engineers call a "brute."

Its elements are vertical racks securely anchored to terra firma, parallel racks built integral with the lock; hollow riveted steel, rolling shafts parallel with the locks and carrying pinions which mesh with the opposite parallel racks on the lock and on terra firma, the shaft having no bearings, but hanging upon its engaged teeth. When the locks move, the shafts roll between the racks and traverse one-half the stroke of the lock.

The preferred form of rack is the ladder type, with pin teeth. Small lock pinions may be cast. For large locks they must be built up of rolled steel, the core a forged drum, the blanks rolled steel rings with involute cut teeth. Such a gearing would give undue wear, were it always subject to maximum working pressures, but for a lock it is, perhaps, the ideal form, as normally the teeth carry only the weight of the shafts; the maximum pressures, due to accidental unequal loading, being infrequent. In the Lockport

locks the shafts are 4 feet in diameter, made of inch plate.

The pinions are double, cut on rolled blanks, 6 inches thick, the involute teeth 16 inches pitch, 60 square inch section at pitch line, 16 pinions and 960 square inches of metal in the teeth being in action.

The outside rack stringers are 15-inch channels, with inch webs, and the teeth 6-inch pins, riveted in.

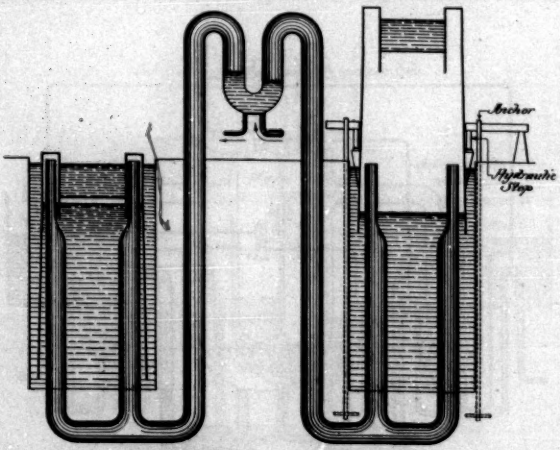


DIAGRAM SHOWING
AIR CONDUIT & VALVE

AIR CONDUITS.

The air main is 13 feet in diameter, and will transfer the entire air charge from lock to lock in one minute, with 330 tons surcharge in one lock.

The connection with each lock is by two open-ended standpipes, 10 feet diameter, which extend from the bottom of the lock pit considerably above the water surface, under hoods formed in the lock body. From their ends rock-cut tunnels run to the risers, which connect with the main valve.

The main valve is a "U" bend, provided with water inlet and drain pipes, so that the bend may be trapped with water and untrapped to shut off or permit the flow of the air.

The water-supply and drainage to and from the valve is controlled by pneumatic weirs, which are the reverse in principle of the air valves. A water-feed pipe extends from the upper level of the canal to the lower part of the main valve, and is formed like an ∽, with upper and lower bends. A simi-

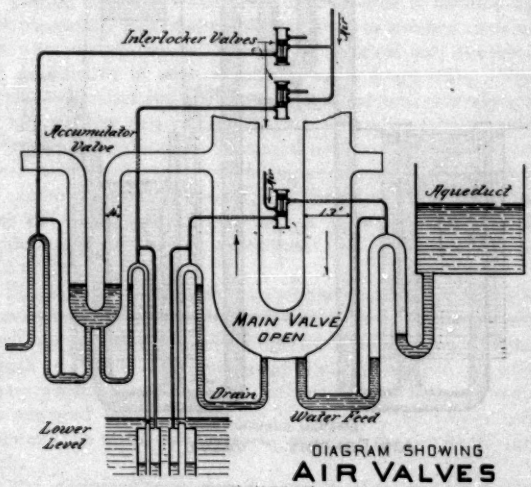


DIAGRAM SHOWING
AIR VALVES

larly formed drain connects to the bottom of the main valve, rises to an upper bend and descends into and is sealed in the water of the lower level.

Air-supply pipes lead from the upper bends of the said water-feed and drain pipes to a 6-inch double-acting air valve, which is part of the interlocking machine in the operator's house. When this 6-inch air valve is moved to "feed" the air to the weir of the water-feed, and to "waste" the air of the

drain weir, the air pressure enters the upper bend of the feed and seals it against the pasage of water; at the same time the air pressure wastes from the upper bend of the drain and the water drains out of the main valve, opening it to the passage of the air.

When it is desired to close the main valve, the 6-inch air valve at the interlocker is moved to "feed" the air pressure into the weir of the drain and to "waste" air from the weir of the feed.

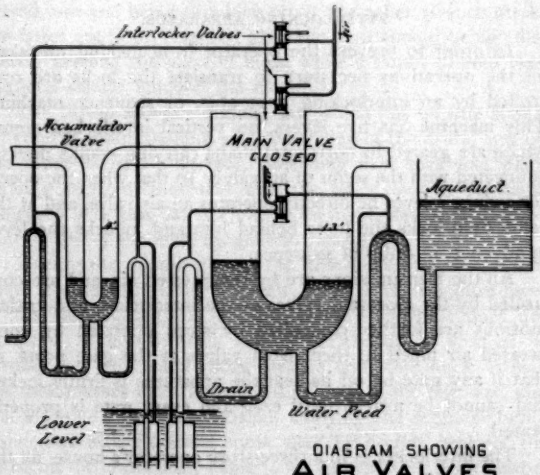


DIAGRAM SHOWING
AIR VALVES

The air escapes from the feed weir and permits water to flow from the upper level into the main valve and seal it, and such water seal is prevented from escaping by the air-trap in the upper bend or weir of the drain.

Similar valves, 4 feet in diameter, open into the legs of the main valve and connect by a 4-foot main with a pneumatic accumulator, which may be thereby connected with or cut off from either lock.

PNEUMATIC ACCUMULATOR.

The pneumatic accumulator is a cylindrical bell, or open-bottomed air tank, having an upper weight chamber filled with water, and gives a constant working air pressure. When a lock is elevated it is immediately connected with the accumulator, which maintains a constant working pressure and automatically compensates for varying density and temperature in the adjacent atmosphere, which would otherwise vary the working pressure.

INTERLOCKING APPARATUS.

In order to prevent the operator from making mistakes, all the operations necessary to translate the locks are controlled by an interlocking apparatus, or sequence machine. This machine has five levers, on vertical interlocked stems, which are geared to horizontal shafts carrying cranks directly connected with the stems of air valves, so that when the operator swings a lever he directly operates an air valve, and at the same time locks the lever behind him and unlocks the lever in advance, in order of sequence.

All the transmissions are by compressed air, and are controlled by the aforesaid valves of the interlocker, and critical motions are further controlled by stops operated by compressed air piped to them from valves at the gate posts, so that if any gate be off its seat the apparatus is firmly locked and cannot be moved until each and every gate is properly seated.

The interlocker is in a three-story operator's house, all the valves and pipes being in the lower, the operating story containing only the levers and the table which carries them.

The tubular valves have balanced spools, cup-leather packings and bronze-lined shells.

AUTOMATIC STOPPING MACHINES.

The automatic stop machines prevent the locks from rising too high, or running away, and control the amount of surcharge taken on the elevated lock, which is the working force

of the system. To this end they control the hydraulic valves of the hydraulic stops.

Because air is elastic, the motions of the ascending and descending locks are not exactly synchronous, the ascending lock leading the descending lock. Therefore, stop machines are independent for each lock. They operate only when the lock is in the upper limit of its stroke, and are adjustable to compensate for varying heights of water in the upper level.

Each lock operates its machine by chain gearing turning its main shaft, which carries a drum having a differential thread, one end being of 1-inch pitch, the other 36-inch pitch, the latter cut in an enlarged part, the slow thread being idle, merely keeping the parts in mesh while it is not desired that the lock should function the machine.

The thread moves a sliding bar, which has on one face a differential tooth meshing with the thread of the drum, and on the other an operating face, consisting in a rack and plain guiding surfaces coincident with the pitch lines of the rack. Engaged with this bar is a pinion segment, having a toothed portion and plane faces tangent to the pitch circle.

During the greater part of the lock stroke the differential tooth meshes with the slow thread on the drum, the plain faces of the bar and segment engage, and the machine does not function. When the lock approaches the upper limit of its stroke, the differential tooth meshes with the quick thread, the rack meshes with the toothed portion of the segment, and the machine functions; the shaft carrying the segment being connected with a parallel crank shaft by double gearing, the gears on the crank shaft being loose and rotating it by ratchet gearing, so that it is always turned in the same direction, whichever way the segment may be rotated. One end of the crank shaft connects by a crank and link with the main hydraulic valve. The other connects with a positive differential crank motion directly actuated by compressed air from the interlocker, and such that dead centers are avoided and the slip of the valve is taken up twice during the complete cycle. The lock opens and closes the hydraulic valve by rota-

ting the segment. The operator opens the said valve, takes up slip, and brings it to a fixed position by admitting compressed air to a piston of the differential apparatus, which is so geared that when the differential crank rotates 144°, the valve crank rotates 210°, and when the lock rotates the valve crank 150°, completing its revolution, the differential is rotated 216°, and completes its revolution.

HYDRAULIC ACCUMULATOR INTENSIFIER.

This machine gives the operator perfect control of the elevated lock. It is so designed that by operating a valve it will give either a higher or lower working pressure. When the lower pressure is admitted to the hydraulic stops, the lock will retract the stops and raise the accumulator weight. When the higher pressure is admitted to the stops, they will force down the lock.

The weight is a tubular concrete block, with an annular water tank for increasing the load. The frame is central in the well of the weight and sustains the hydraulic members, which are a lower 20-inch cylinder, a 20-inch ram carrying the weight and bored to form the cylinder for an upper 11½-inch ram working therein.

The two cylinders are connected by a valve-controlled pipe. When the valve is closed, all of the water expelled from the 20-inch ram is piped to the hydraulic stops, the pressure being 1,086 pounds. When the valve is open, one-third of the water expelled from the 20-inch cylinder goes into the 11½-inch cylinder and intensifies the pressure, raising it to 1,623 pounds.

This is an example of work equivalent. The work done is the descent of the accumulator weight. If all of this work goes into the stops, their work collectively is equal to the volume swept through by the acumulator ram at low pressure. If but two-thirds of the water passes to the stops, and one-third goes to the intensifier, it is evident that the same work must be done by the stops in a stroke two-thirds of the stroke of the weight, and, therefore, the pressure must be increased one-half.

The machine is also a mechanical proof of the mathe-

matical summation of series. In the case given the intensifier ram is practically one-third the area of the accumulator ram. Therefore, when the valve is opened, the pressure in the accumulator cylinder reacts through the intensifier cylinder, and raises the pressure in the accumulator one-third. This one-third reacting in the same manner, raises it one-ninth. The one-ninth increase raises it one-twenty-seventh, which raises it one-eighty-first, which raises it one-two-hundred-and-forty-third, and so on to summation:

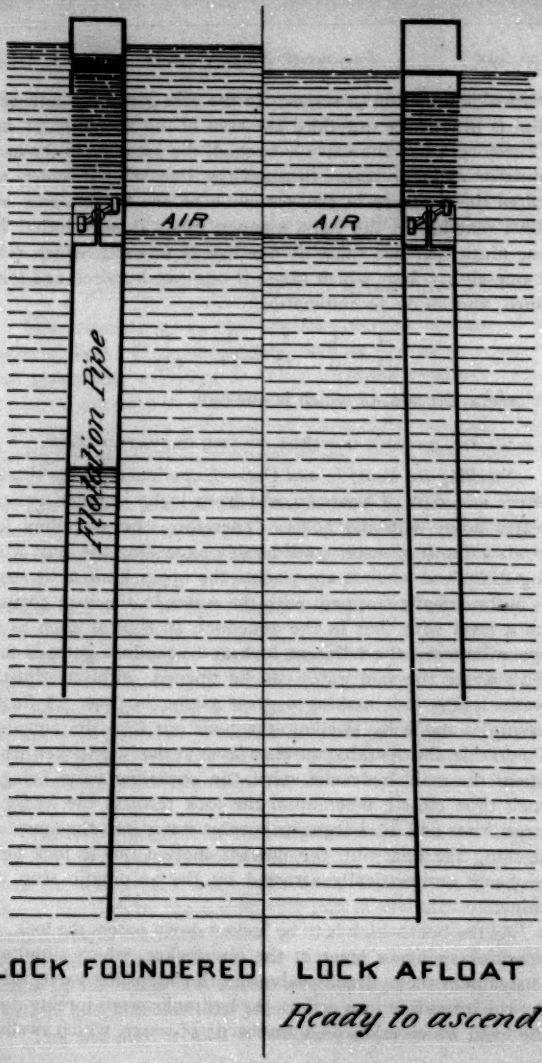
$$\frac{1}{3}+\frac{1}{9}+\frac{1}{27}+\frac{1}{81}+\frac{1}{243}+$$

et cetera, the sum of which is one-half.

OPERATOR'S CONTROL OF THE ELEVATED LOCK.

Swelling the Boats In and Out.—Experience proves that the entry and exit of boats to and from locks is much easier if water flows with the boats. Therefore, the ascending lock holds a depth of water considerably exceeding the least working draft, and when it approaches the upper limit of its stroke is automatically stopped, with the water in the lock chamber on a level with that in the aqueduct, so that as soon as the space between the adjacent lock and aqueduct gates is filled with water the said gates can be opened, without adjusting water levels, thus making a great saving in time. A further saving is made by swelling the boat out into the aqueduct. To do this, the operator moves a lever at the interlocker, which opens the main hydraulic valve, the intensifier valve being at such time closed, whereupon the lock retracts the hydraulic stops, rises and discharges its surplus water into the aqueduct, swelling the boat out, the upward motion of the lock being properly automatically arrested by the automatic stop machine.

As the boat which is to be locked down enters the lock, the operator swings a lever in the interlocker, which simultaneously opens the hydraulic valve and the intensifier valve, bringing the intensifier into action, the hydraulic stops forcing down the lock, which takes on a surcharge of water, which swells in


AIR
AIR
Ventilation Pipe
LOCK FOUNDERED
LOCK AFLOAT
Ready to ascend

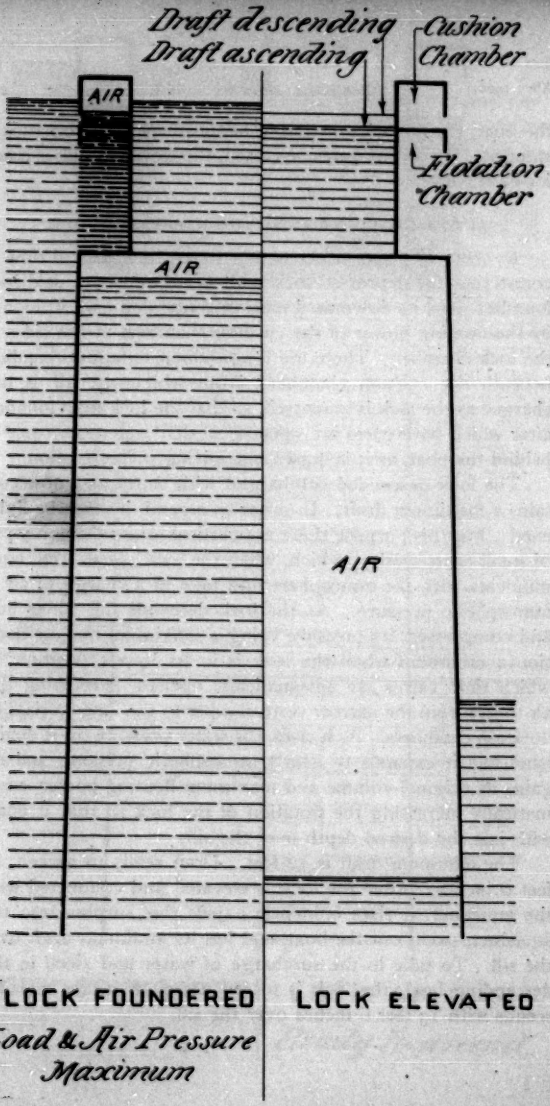
the boat, the downward motion being properly automatically stopped. If now the gates be closed, the elevated lock is ready for its traverse.

AUTOMATIC CONTROL OF THE DEPRESSED LOCK.

In order to avoid nicety of adjustment and loss of time in connecting the depressed lock with the lower level, said lock founders until its downward motion is arrested and cushioned by the floating power of the cushion chambers at the sides of the lock chamber. There are longitudinal flotation chambers beneath the cushion chambers, from which the air is discharged as the lock is immersed, so that the lock may founder; after which both gates are opened, so that water can come in behind the boat, as it is drawn out, giving it free motion.

The lock descended surcharged with water and now contains a maximum draft. In order to ascend, it must be lightened. For this purpose there are vertical long flotation pipes, of small cross-section, which, when the lock is elevated, communicate with the atmosphere and take in a charge of air at atmospheric pressure. As the lock descends this air is held and compressed, its pressure being a maximum and its flotation a minimum when the lock is in its lowest position; at which time valves are automatically opened, permitting this air to rise from the narrow vertical pipes to the long horizontal flotation chambers. As it rises, the water pressure on it diminishes and it expands to nearly atmospheric pressure and regains its original volume and maximum floating power, automatically increasing the flotation of the lock so that it floats with just the desired depth over the sill.

The minimum draft is 12 feet. Draft ready to ascend, 12 feet 6 inches. After the lock is elevated and connected with the aqueduct, it rises 6 inches, expels this surplus into the aqueduct, swells out the boat, and has its minimum draft over the sill. To take in the surcharge of water and swell in the descending boat, the lock is forced down 18 inches and descends with 13 feet 6 inches over the sill.


Draft descending
Draft ascending
Cushion Chamber
Flotation Chamber
AIR
AIR
AIR
LOCK FOUNDERED
LOCK ELEVATED
Load & Air Pressure Maximum

AUTOMATIC INCREASE AND EQUATING OF AIR PRESSURE.

While the lock is moving, it is obvious that the air pressure cannot vary greatly from the pressure which would be in exact equilibrium with the load. If the walls of the chamber were parallel, the working margin of excess pressure must be greater, because the pressure of equilibrium would necessarily increase as the lock rose and the immersed portion of its walls became less; therefore, the locks are equated, so that the working pressure or pressure of equilibrium is constant, the sides being splayed, so that the projected area against which the pressure acts increases in a constant ratio from the upper towards the lower portion of the air chamber, with the decreased immersion of the walls.

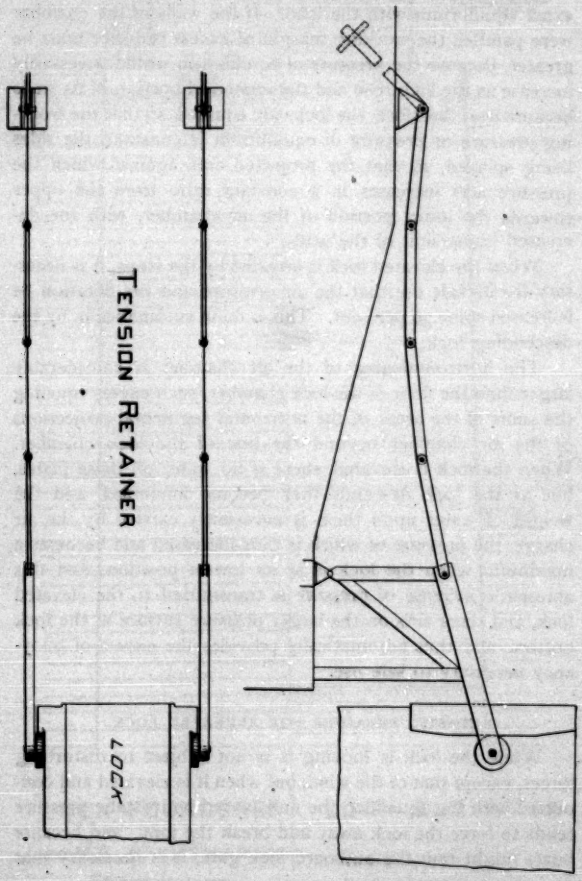
When the elevated lock is arrested by the stops, it is necessary for its safe use that the air pressure and the flotation be increased some 30 per cent. This is done automatically by the descending lock.

The horizontal area of the air chamber is considerably larger than the floor of the lock chamber, such excess equaling the sums of the areas of the horizontal segmental projections of the air chamber beyond the line of the lock chamber. When the lock is elevated, there is no water on these plates, but as the lock descends they become immersed, and the weight of water upon them is necessarily carried by the air charge, the pressure of which is thus increased and becomes a maximum when the lock is at its lowest position; and this automatic increase of pressure is transmitted to the elevated lock, and there acts on the larger pressure surface at the lock bottom, and thus automatically provides the excess of buoyancy necessary to safe use.

ELASTIC RETAINER FOR ELEVATED LOCK.

While the lock is moving it is not subject to disturbing forces, except that of the wind, but when it is elevated and connected with the aqueduct, the unbalanced hydrostatic pressure tends to force the lock away and break the joint; and because boats might ram the outboard lock gate, it is necessary that

the connection have flexibility to cushion the blow. These ends are compassed by tension retainers, which are I-bar cables, 220 feet long, hanging in catenaries, anchored at one



end to the bed rock, at the other retaining the hydrostatic pressure in the end of the aqueduct, or in the lock when connected, the connection being retaining wheels, 12 inches thick, 5 feet diameter, with 15-inch journals, adjustable in bearings formed in the end frames of the retainers, the wheels engaging shoulders on the lock, which are runways planed on heavy steel castings, riveted into and forming flanges of the portal columns of the lock body. A blow will pull the cables into flatter curves, the endwise motion cushioning the shock.

The joint is made water-tight by a dilatable rubber tube, secured to the aqueduct face, and seating at any point on a flat timber apron provided on the adjacent end of the lock. The tube is cured flat, and remains so when deflated. To make a joint, it is inflated by compressed air admitted from a valve of the interlocker. The space between the gates is flooded and emptied through pipes controlled by pneumatic weirs, which, in turn, are controlled by air pipes leading to valves at the interlocker.

POWER PLANT.

There is a 36-inch double-balance turbine, belted to a duplex air compressor, to a four-cylinder, high-pressure hydraulic pump, and to a dynamo for lighting. Also a high-pressure air tank, and a tank for the hydraulic supply, it being intended to operate the hydraulic apparatus with 500° test petroleum.

AQUEDUCT.

The necessity of operating the old locks while the new ones were being built compelled the use of an aqueduct, 393 feet long, to connect them with the upper level. This aqueduct is so designed that the strains due to the static load oppose and cushion the strains induced by collision of vessels using the aqueduct. This principle develops the full elastic quality of the steel, makes the sides four times as flexible, and the flange strains less than one-eighth as great as those obtaining in aqueducts heretofore designed; the builders of which appar-

ently ignored the destructive effect of shocks or assumed that the boats could be drilled so as not to collide.

In structures of the old type the flange strains in the frames are due to the sum of the static and shock moments, and the elastic cushioning movement of the side walls is that due to the variation in the one kind of strain, for example, tension, to which the flange is subjected. In the design exhibited, the flange strains are equal to one-half the difference between the static and shock moments, and reverse from tension to compression, or *vice versa*, so that the elastic movement is four times as great, the greatest which the metal is susceptible of without injury.

GENERAL PRINCIPLE OF CONSTRUCTION.

The floor is not framed, but suspended at the edges, and the weight thereon exerts an inward pull on the frames in opposition to the hydrostatic pressure on the sides. By suitably proportioning the parts, these forces can be given any desired ratio. The inward moment of the floor exceeds the sum of the outward moments, and induces compression in the upper and inner flanges, and tension in the outer and lower flanges below the floor line. When a boat strikes the side, the stresses are reversed.

This particular design could not be applied to the end bays, where the gates are located. Therefore, the principles were applied in a different manner, the flat floor being carried by transverse girders spliced to the side walls, which are framed as girders and connected to the inner vertical flanges of the frames which are suspended from their outer flanges on links and pins, so that under the static load the outer and under flange is in tension, and the upper and inner flange in compression. When the boat strikes one side, its shock is cushioned by the elasticity of the entire frame, and before it can have a destructive effect, it must reverse the strains in both flanges, swing the end of the aqueduct to one side and somewhat raise it. This design can be made much more effective with an equal weight than that adopted for the intermediate bays, because the shock is cushioned by the elasticity of the

entire frame, whereas the other design cushions by the elasticity of half the frame.

As the designs for the aqueducts have been very materially improved since this address was delivered, the reader is referred, for full information concerning them, to U. S. patents 621,470, of March 21, and 626,321, of June 6, 1900, issued to the author.

While every precaution has been taken in the design to prepare the structure safely to resist a maximum shock, the interior of the aqueduct is protected with elastic timber guards, which, if they be properly maintained, will absorb the greater part of the shocks without much strain to the structure. But, obviously, a structure which may be put into the keeping of incompetent men, appointed for political purposes without regard to their fitness, must be so designed that no fool can cripple it, so that it might be wrecked by improper use. Therefore, the aqueduct is designed with such great care, and is much more costly than would be desirable were it owned and operated by a private corporation, which would exercise reasonable care in its use and maintenance. The same is also true of the locks.

HOW THE LOCKS WORK.

The depressed lock floats and requires no care. The elevated lock is connected with the pneumatic accumulator, and the air pressure in it is 8¼ pounds per square inch, which expels from it a weight of water 30 per cent. greater than the weight of the loaded lock, giving it the excess buoyancy necessary to its safe use; said excess buoyancy being restrained by the anchors. When the elevated lock first ascended, it engaged with the retainer, the joint was packed by inflating the rubber pipe, the space between the lock and aqueduct gates was flooded with water, the gates were opened, the boat was swelled out into the aqueduct, to accomplish which the hydraulic valve controlling the stops was opened and the lock retracted them and raised 6 inches. As the descending boat entered the lock, the intensifier was brought into action, the lock was forced down 18 inches and took on its surcharge of

water, swelling in the boat, such lock motions being automatically stopped by the stop machine. The gates of the depressed lock, and the adjacent gates of the elevated lock and aqueduct can now be closed, and the space between them drained. The accumulator valves are now closed, the main valve is opened, and the air expands from the elevated lock into the depressed lock, raising it and at the same time lightening it as it rises, by reducing the extraneous load of water on the projecting horizontal segmental plates at the tops of the air chambers. This function continues until the air in the elevated lock has expanded to less than equilibrium with the weight thereof, so that the elevated lock can descend, at which time the depressed lock has been raised so high and the extraneous load therof so decreased, that the pressure of equilibrium therein is less than in the elevated lock, from which time the depressed lock ascends until it is fully elevated and is brought to rest by the hydraulic stops, and the elevated lock descends until the segmental plates at the tops of the air chambers are immersed and begin to take on the extraneous load, which increases as the lock descends, and the plates are immersed to greater and greater depth, such extraneous load and the air pressure becoming maximum when the lock has descended to its lowest position. This maximum pressure acts in the elevated lock at the large bottom portion thereof, and induces therein the excess buoyancy necessary for its safe use. The main valve is then closed, and the accumulator valve opened, connecting the accumulator with the elevated lock, which can then be connected with the aqueduct. Both gates of the depressed lock are then opened, which is thereafter automatically floated to a higher position relatively to the surface of the water of the lower level, in which it floats, so as to contain the draft of water with which it should ascend.

The pneumatic lock will wholly change the conditions of canal construction. Heretofore, the range of usefulness and the location of canals have been limited by the water-supply available for feeding the locks from the summit level, and it has been necessary to maintain the water level within narrow

limits; and the large amount of water and the heavy currents necessary in locking have necessitated a constantly running supply and spill ways for the escape of such supply, when the locks were not operated. The small lift of the Leonardo locks necessitated the selection of gentle slopes for the lock sites, which, in many cases, involves soft foundations. In

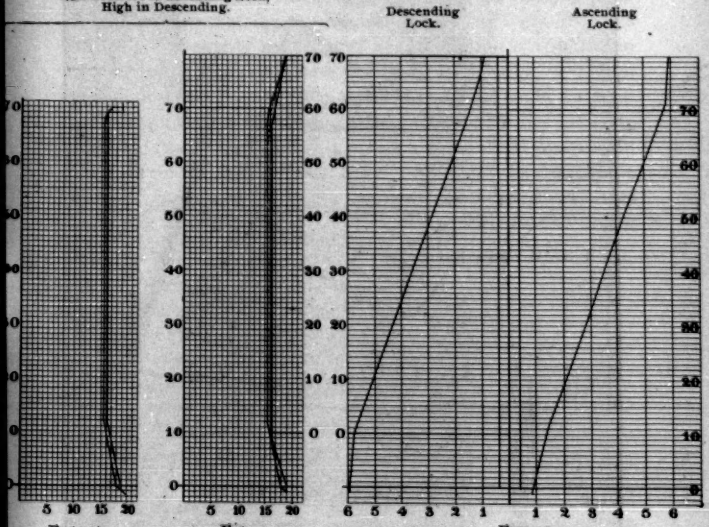


FIG. 1. FIG. 2. FIG. 3.

Vertical ordinates read stroke in feet. Abscissas read feet of water pressure, or "head" on air charge, in *Figs. 1* and *2*; and in *Fig. 3* read 100,000 of cubic feet of compressed air as distributed between the two locks during their cycle, the central ordinate indicating the position of the valve and the adjacent rectangles the conduits. In *Fig. 1* the stroke of the descending lock reads downwardly, with the motion; in *Figs. 2* and *3* all strokes read upwardly so as to show relatively coincident conditions in the two locks.

canals planned with pneumatic locks, the most economical plan will be to make the levels as long and the locks as high and few in number as possible. Guard locks and the waste of

1897
ERIE CANAL IMPROVEMENT
COHOES LOCKS

water can be entirely dispensed with, and the summit level can be utilized for storage, its banks being high enough to contain the highest and its bottom low enough to give the desired draft at the lowest water, the variation being taken up at the lock. In most canals the heavy tonnage is one way, and down hill. In such cases the descending tonnage will not only operate the lock, but also lift water to the summit level. It will be seen that the first cost of canals and their demands on the water-supply are reduced to a minimum. Application of steel to the locks reduces their cost of installation, operation and maintenance as greatly as it has reduced such costs in other engineering structures. The State authorities estimate that the saving in wages at Lockport will exceed interest on the entire cost, and at Cohoes such saving will be double the interest on the cost of installation, so that building the Cohoes locks will save an actual profit. In ship canal locks the saving will be in ratio increasing with their size.

Mining and Metallurgical Section.

Special Meeting, held Wednesday, January 31, 1900.

FLUSHING OF CULM IN ANTHRACITE COAL MINES.

By Wm. Griffith,
Mining Engineer.

From 15 to 20 per cent. of the coal won from the anthracite coal mines according to the methods of the past was ground so fine in the course of preparation through the breaker that it could not be used or sold, and had to be piled away as refuse. The method of doing this, and which is still largely used, is to haul the culm, as it falls from the chute, to the foot of a plane. It is then hoisted up an incline to the top of a large pile and pulled to the dumping ground by a mule, all of which process costs in the neighborhood of a cent or more per ton for the total output of the mine. The result is that at every an-

thracite mine there are to be found immense piles of refuse which are not only unsightly, but occupy considerable areas of ground which it would often be very advantageous to use for other purposes. By the wet process of preparation, though the culm is flushed into streams with water, similar objections hold.

Of late years many of these culm piles are being reworked and the coarser portions screened out and sold for use as steam sizes, leaving the finer culm still as a waste material. Furthermore, the improvement in methods of burning fine coal has been so marked that the culm or waste produced by present methods of preparation in modern coal breakers is not much larger than the printed letter of this page. Recently, however, a new process has been originated for disposing of the waste from the mines, which has been called "flushing." By this process the culm and waste material is carried back into the mines, with water, and allowed to fill part of the abandoned portions of the underground workings. This scheme was first resorted to in 1887, by the Philadelphia and Reading Coal and Iron Company, at their Kohinoor Colliery, near the city of Shenandoah, in the Schuylkill region. Here the Mammoth Vein is about 60 feet in thickness. An immense cavity about 100 yards square had been excavated by former operators, under valuable property in the city of Shenandoah, and it was feared that in case a cave should occur it might cause great damage. In order to prevent this, the cavity was filled with culm from an adjacent culm pile, flushed in with water, through a series of bore holes which were bored for the purpose. The success of this experiment excited considerable comment throughout the anthracite region, and resulted eventually in the repetition of the process at other collieries, for various purposes.

In the Northern coal field the process was first introduced in about the year 1892, at the Dodson and Black Diamond Collieries, operated by Mr. J. C. Haddock, under the superintendency of Mr. James B. Davis. Mr. Davis has since prepared a very careful and exhaustive paper upon the subject, which goes fully into the practical details of the

operation. This paper was read on January 12, 1898, at a meeting of the Anthracite Coal Operators' Association, in New York, and was subsequently published in the monthly letter of this Association, issued in February, 1898. Also in March and April issues of *Mines and Minerals*, Scranton, Pa.

This process of flushing is now in operation at many other collieries throughout the anthracite coal region, although the great majority still cling to the older method of depositing the culm on the surface.

The process is a very simple one. The culm, as it accumulates in the breaker, is carried through a system of "telegraphs" or conveyors to a hopper—usually an oil barrel. A stream of water is also conducted into the same hopper by means of a 3-inch pipe, and the culm is carried by the water through a pipe usually 4 inches in diameter, passing out of the bottom of the hopper. This pipe passes down into the mines through the shaft, or by means of a bore hole, is conducted along the gangways and up the chambers through the cross-cuts to the point where it is desired to deposit the culm. The pipe used is ordinary black wrought-iron pipe. The joints are ordinary screw joints; or more commonly a piece of 4½-inch pipe, about 8 inches long, is split on one side and placed around the pipe, being held together by two clamps. This form of joint is very simple and easy to apply. It leaks for a short time after being put on, but the crevices are soon stopped by the culm and the joint becomes tight. This pipe may be carried from the foot of the shaft either up or down the pitch. Of course, if it is carried up the pitch, more water is required to deliver the same amount of culm than is the case where the pipe is carried down the pitch or level. The culm flows freely through these pipes for long distances, and may be deposited at almost any point in the ordinary anthracite mine. The water is usually turned on about fifteen minutes before the work starts at the breaker, and is allowed to run for about fifteen minutes after work stops in the evening, in order to thoroughly clean the pipe. Occasionally stoppages occur when the pipe becomes filled with culm from one end

to the other, which of course requires considerable time and trouble to again clear. It is usually accomplished by breaking a joint near the foot of the shaft and allowing the pressure of the water to force the culm out of a section 100 or 200 feet in length. Connection is then made and again

broken several lengths farther on, and the water used to again clean the pipe. This process is continued until the pipe is all cleared.

The culm issuing from the pipe is discharged in the highest point of the chamber or portion of the mine desired

to be flushed, and stoppings are placed at the outlets of the chambers, near the gangways. The culm, as it is deposited from the end of the pipe, takes a very flat slope, and is carried a long distance by the water, which ultimately sinks away and filters through the deposited culm to the lower

portion of the mine, where it is pumped to the surface by the mine pumps.

The stoppings which are used are often simply board partitions placed across the end of the chamber and fitted closely; or sometimes dry walls of slate or mine rubbish are

used, a dike of culm being piled behind the wall, through which the water may filter.

When the chamber is filled to the roof the pipe is withdrawn and culm allowed to run into the next chamber, and so on the process continues until the desired area is completely filled with culm.

There are many details of the process which we do not care to enter into at this time. They will be found to be explained at length in the article previously referred to; as also the items of cost and the various advantages of the process from the cost point.

In general, it may be said that the net saving by flushing varies from $5 to $15 per day. In addition to this good showing in favor of the flushing process from the viewpoint of the expense, the advantages of the process are many, perhaps the greatest of which is the help that may be afforded the pillars by flushing culm at the time of a squeeze in a coal mine. During the past years, of course, the coal in the anthracite region has been mined largely from the upper seams, and from those from which coal could be won at the least expense, leaving the deep coals and expensive, dangerous mining for the future. During the mining of these shallow seams with thin overlying roof, the question of squeezes in the coal mines was a matter of comparatively small moment, but now that we are beginning to mine in the deeper portions of the measures, it becomes one of paramount importance. The squeezing and caving of our mines, owing to excessive weight on the pillars, has been the cause of many of the most serious and expensive mine accidents and awful disasters by which many lives have been lost, as well as much property, and will continue to be one of the great dangers of future mining in the deeper measures of the anthracite field. It has been customary in the past to leave about one-third of the coal in the ground, in the shape of pillars to support the roof, but experience now shows that it is necessary to leave a larger amount to support the roof in the deeper lying seams, because pillars composed of one-third the seam are not strong enough in all cases to sustain the weight. Besides this, in

some coal seams the pillars, after long standing, are so affected by the action of the air, heat and pressure that they splinter and chip around the margin, and pieces keep continually falling off. This process, if long continued, will often so impair the pillars of an old working, that they become too weak to support the roof, and a cave or squeeze is started. It often happens, also, that in otherwise well-conducted coal mines a limited area of the workings may be so mined that the pillar area averages much less than is intended by the management, and a weak point is made which may start to squeezing. Whatever may be the cause, a squeeze usually starts at some weak point in a mine. And inasmuch as the crushing strength of anthracite coal is about twice the weight required to start it to squeezing or cracking, a considerable time elapses from the moment that the squeeze begins until a crush finally occurs, and, as a rule, ample warning of the impending danger is given by the snapping or grunting of the pillars. As the squeeze progresses at the point of weakness, the pillars become less able to support the overlying weight; consequently, the pressure is transferred to the surrounding pillars, and the result is that the squeeze gradually progresses from the weak point to the other or stronger parts of the mine, gradually squeezing the pillars as it progresses, due to the immense leverage on the adjacent pillars which are still intact.

The method of preventing such squeezes in the past has been to build cribs or "cogs," as they are called, of logs from the floor to the roof and fill them with rock and other refuse of the mines, until a sufficient number of these cogs have been built across the line or direction of the squeeze to take the weight from the adjoining pillars and cause a crack in the roof, which immediately relieves the strain on the adjacent pillars, and the squeeze will stop. Of course, considerable settlement of the roof will occur before the cogs will take the weight, and at best this system of stopping a squeeze in the mine is very imperfect, uncertain and dangerous; whereas, if the weak point of the mine can be filled full of culm by the flushing process, it forms a

barrier which no squeeze can cross. The culm effectually fills up the cracks and crevices, all the interstices in the mine gob, and finds its way under the center of the affected parts where no man would dare to go, causing an effectual barrier capable of sustaining an immense weight; also protecting the pillars from further chipping, by excluding the air.

Now the question arises and is of considerable interest, as to how much the confined culm will be compressed by the weight of the roof, or how much it will settle. Mr. Davis ascertained by experiment that a cubic foot of anthracite coal ground to culm would be flushed into a space of nearly $1\frac{1}{2}$ cubic feet. Therefore it was impossible to compress the culm more than one-third, because it would then occupy the same space as the solid coal. In order to determine the compressibility of culm under these conditions, we have recently made a few experiments in this line. The first and second experiments were with wet culm; the third with dry culm. A section of 4-inch wrought-iron pipe $9\frac{1}{4}$ inches long was flushed full of culm and after the water had drained off, was placed in a hydraulic press and the pressure required to compress the culm noted. The same was done in the second experiment, using a pipe 3 inches internal diameter and $15\frac{1}{4}$ inches long. In the third test a cylinder of cast iron $3\frac{3}{8}$ inches diameter and $13\frac{7}{8}$ inches long was flushed full of culm and placed on top of a nest of boilers for about a week until it became thoroughly dry. The results of these tests are shown in the following tables, indicating tests Nos. 1, 2 and 3 in triple columns. It will be noted that, other things being equal, dry culm will withstand two or three times the weight of wet culm. It requires a long time for culm to dry after being flushed into the mine. It is not often, therefore, that dry culm could be depended upon to withstand the weight of a mine squeeze. However, when it does become dry it is so firmly compacted that gangways may be driven through it having vertical walls of culm on either side which show only a slight tendency to caving.

While these tests are very crude and the results are

rather varied and altogether unsatisfactory, still, so far as our knowledge goes, they are the only tests ever made in this particular line and we trust are only the beginning of more extended ones to be carried forward under more exact methods and more favorable conditions. They are introduced here because they will serve to at least give a better idea of the extent to which culm may be depended upon to hold the roof of a caving mine, which has heretofore been a matter of mere conjecture by engineers of the coal fields.

Compression in Inches.	Weight in Tons.			Tons. Weight Per Square Inch.			Per Cent. of Compression.			Remarks.
	1	2	3	1	2	3	1	2	3	
½	—	2	6	—	·29	·67	—	3·48	3·7	
1	—	4	9	—	·57	1·0	—	6·56	7·44	
1½	7	6	14	0·56	·85	1·57	16	9·83	11·16	
2	13	8	23	1·04	1·14	2·57	21·6	13·12	14·88	
2½	34	12	35	2·72	1·71	4·0	27·0	16·3	18·6	Test No. 1. Pipe began to expand.
2¾	34	—	48	—	—	5·4	—	—	20·46	Test No. 1. Pipe burst.
3	—	19	56	—	2·71	6·26	—	19·67	22·34	
3¼	—	—	61	—	—	6·82	—	—	24·18	
3½	—	26	—	—	3·71	—	—	22·14	—	
3½	—	—	70	—	—	7·83	—	—	26·04	
3⅞	—	38	—	—	5·43	—	—	25·42	—	Pipe burst.

Test No. 1. 4-inch gas pipe 9¼ inches deep, flushed full of culm and drained.
" " 2. 3 " " " 15¾ " " " " " " " "
" " 3. 3½ " cast cylinder 13⅛ " " " " " " "thoroughly dried

We note by test No. 2 that to produce a compression of 10 per cent. would require about $\frac{9}{10}$ of a ton in weight per square inch. Therefore, in a 5-foot seam of coal, if we assume the superincumbent strata to weigh about 145 pounds to the cubic foot, a pressure of about $\frac{9}{10}$ of a ton per square inch would be produced by a column of sandstone 1,800 feet high. In a 5-foot seam which had been completely flushed with culm the compression caused by this weight would be about ½ foot, an enormous resisting power.

From the experience of the past, as well as tests which

we have recently made, we know that the pillars of a coal mine will begin to squeeze when the pressure upon them amounts to from 400 to 4,000 pounds per square inch, depending upon the thickness of the bed, quality and firmness of the coal and the conditions under which it is mined. Therefore, for example, to show the utility of flushing, if we assume mining at 500 feet depth in a bed in which we know by test that the weakest bench of coal will begin squeezing at 1,500 pounds per square inch, if two-thirds of the coal in such a mine be exhausted, we know we have a weight on the pillars which is liable to start a squeeze at any moment, particularly if in any part of the workings the pillars average less than one-third the whole, or the pillars of the seam are subject to much chipping. Therefore, by examination of the mine and the maps, the engineers may select the weak points and flush them with culm, knowing that if a squeeze should start, the roof could settle only about 3 to 8 per cent. of the thickness of the bed; or, if the culm were dry, only about 2 per cent., after which the culm would take the weight and stop the squeeze. From which it may readily be seen that culm flushed into the mines by this process becomes an ample and positive safeguard against the crushing of the mine, if properly done. Of course, in case of robbing or remining the pillars after flushing, the settlement would be much greater than above stated, unless the space formerly occupied by the pillars be reflushed.

The advantage also of culm as a preventive of mine fires must be conceded. It has been supposed that the culm thus deposited would be subject to spontaneous combustion, as is so often the case with culm piled on the surface. Experience, however, shows that spontaneous combustion is not liable to occur under these conditions. Many tests have been made by digging through the culm to the bottom rock, but in nearly all cases no sign of heat or fire has been discovered, and there is no case on record, so far as we are informed, of the culm thus deposited taking fire spontaneously.

We know of no attempt to use a mixture of culm with water for the purpose of drowning a mine fire, but it would

seem that it might readily be used for this purpose, since by placing the proper stoppings around the fire, as is usually done, for excluding the air, that water and culm could be flushed in through borings from the surface until the space was completely filled with wet culm. This method would effectually exclude the air, and in all probability stop the fire, particularly if water was kept running in the bore hole, so that it could seep through the culm, in order to keep it wet.*

There are many other advantages which might be named in favor of this process, but we have not time to consider them here. There is one other point, however.

The question will of course arise as to how much additional coal may be mined by first flushing the old workings with culm and then extracting the pillars. This may be safely done and is a very advantageous way of robbing pillars where the surface contains valuable property which cannot be disturbed. The quantity of coal which may thus be recovered in addition to that obtained by the first mining over is a question which is entirely controlled by the thousand and one conditions which obtain at each colliery. In some cases little coal, in others much; perhaps 20 per cent. or more may be saved, providing the mine is worked and portions flushed with the view of remining it. This process has been considered so advantageous that at some particular mines in our Northern coal field they are now taking the culm from the old banks without rescreening to save the small sizes, passing it through rollers to grind up the large particles, and flushing it into the mine for the purpose of filling up, with the idea of remining the pillars or preventing a squeeze at particular parts of the mine, and so on.

It is quite likely that this process will become more and more used as the coal approaches exhaustion, and especially will this be the case in connection with the deep mines of the future. So that this question of the flushing of culm

* Since above was written instances have been recorded where culm has been thus used successfully for stopping mine fires. See *Mines and Minerals*, February, 1900.

in the mines may eventually be expanded to the larger question as to whether or not it may be advantageous, when facilities warrant, to flush sand, loam and other material from the surface into the mines, for the same purpose. In our opinion it is quite likely that we may ere long see the time when this may be done to advantage in particular cases.

ELECTRICAL SECTION.

Read at the stated meeting held November 28, 1899, and discussed at the stated meeting held February 27, 1900.

INCANDESCENT LAMPS.

By Francis W. Willcox.

The commercial incandescent lamp is now in its twentieth year. In this short period it has grown from a weakling to a giant of industry. The value of the manufacturing lamp business of the United States alone aggregates over $2,000,000, with a total production of between 15,000,000 and 20,000,000 lamps per year, and European factories will swell this total output to over 25,000,000 per year.

Assuming the value of a lamp at 20 cents, we have an annual expenditure of between $4,500,000 and $5,000,000, paid for this one detail of electric lighting—certainly a significant index of the great value of the electric industry.

Although an apparently small detail of electric lighting, the incandescent lamp is the most important part of the system.

Some one has well said that the incandescent lamp is the very soul, the essence of electric lighting, and it is an evident fact that electric lighting cannot improve any faster than the art of lamp manufacture permits.

Electric lighting waited for the production by Edison of a successful incandescent lamp. The improvements in electric machinery and methods of distribution, the refined results obtainable to-day, have caused more dependence than ever to be placed upon the incandescent lamp, and have accentuated the need and the importance of the most superior quality of lamp to secure the best results.

The selling price of good lamps has been brought down from $1 apiece to an average of 18 cents. This immense reduction alone would be a great achievement were it not rendered still greater by the great improvement in quality of the product. Measured by the standard of the best lamp of to-day, sold for an average price of 18 cents, the lamps that sold formerly for $1 would be very costly as a gift to any central station.

As we glance back over the field of development we find many features of interest, and I propose this evening to describe a few of the more important and interesting features in detail, such, for example, as:

The improvements in lamp manufacture.

The advance in quality and change in types and standards of lamps, and the improvements in method of supply.

The widened field of lamp use, and the production of special types and forms for special service.

The advance in methods of lamp testing.

The better understanding on the part of purchasers of the essentials of a lamp and of its correct use.

IMPROVEMENTS IN LAMP MANUFACTURE.

The production of a lamp involves many operations, but the real essentials are four in number: Making the filament; treating or "flashing" the filament; joining the filament to the conducting connections; and exhausting the lamp. The remaining processes, such as sealing in bulbs, capping, etc., are mechanical and simple.

The early struggles with platinum, silk, tamadine and various natural fibers, down to the selection by Edison of Japanese bamboo, are well known. The old bamboo filament had many disadvantages. The natural bamboo could not always be obtained of uniform density and character. The filaments were limited in length. The production of the filament by the cutting and shaving of the bamboo sticks involved a large amount of labor and waste of material.

We now beat nature at her own game. We make a fiber any length, size or shape, and we make it uniform. We mould cotton into a filament as the brickmaker makes his bricks, by making a solution, moulding (*i. e.*, squirting it)

into desired shape, then drying out the solvent and baking it.

With the old bamboo filament the Edison factory, for a production of 20,000 lamps per day, employed 350 people cutting fiber. With twice this production of lamps, *i. e.*, 40,000 per day, but twenty-five people are necessary to produce the squirted filaments. With the bamboo over 90 per cent. of the crude material was wasted; with the squirt filament over 95 per cent. is utilized.

The treatment or flashing of filaments has always been rightly considered a most marked improvement in lamp manufacture.

As is well known, all lamp filaments, after carbonization, are subjected to a treating or depositing process. This deposition is accomplished by burning the filament at high incandescence in a chamber in the presence of gasoline vapor. The white-hot filament decomposes the gasoline vapor, depositing a surface coating of graphitic carbon over the filament. It is of interest to note that the reasons for its adoption no longer apply, and that it is retained to-day for other purposes. The early filaments were all untreated.

It was impossible then to make filaments uniform and free from uneven sections or points, and it was very difficult to cut the filaments to a given resistance. The treating process was devised to overcome these difficulties. By filling in the uneven points with the carbon deposit the filament was rendered uniform. The gradual increase of diameter through the carbon deposit allowed the resistance to be decreased to any fixed amount, readily and accurately.

The present cellulose filaments are made both uniform and of the desired resistance, so that treatment is not now necessary for these results. Why, then, is treatment still continued? Because it gives a hard, dense surface coating of graphitic carbon, which is more durable than the filament base of amorphous carbon, and also because it effects an increase in the emissivity of the filament. Consider the case of two filaments, one treated, the other untreated, and both consuming the same current. The surface coating of the treated carbon acts to retain the heat, which is radiated more rapidly from the untreated surface of the other. This re-

sults in raising the temperature of the treated filament above the untreated, and giving a higher candle-power. This means an increase in efficiency, since it is evident that to give the same candle-power less power would be required by the treated filament.

The early methods of treatment required that a filament be treated by steps, *i. e.*, treat a few seconds, then take out and measure, and so on until the desired resistance was obtained. How crude this seems compared to the present automatic Wheatstone bridge arrangement, which instantly arrests treatment when the desired resistance is reached. This arrangement alone has reduced the employés to one-quarter of the number formerly necessary.

The progress in the art of joining filament to connections is clearly shown from an examination of old and present lamps. We trace it through from the early bolt and nut clamp of Maxim, the electro-plated joint of Edison, down to the modern paste and deposited joints—a marked advance toward simplicity and lessened cost.

In the exhaustion of lamps, manufacturing methods were for a long time slow of improvement. What was needed was a rapid and effective method of pumping that would admit of lamps being exhausted singly. With mercury pumps to secure full productive capacity, it was necessary to exhaust lamps in batches of 50 to 100 at a time, so that lamps could not receive the individual attention necessary to secure best results. This same difficulty existed for a long time with mechanical pumps, and, besides, mechanical pumps could not unaided produce the degree of exhaustion desired. The introduction of what is known as the "chemical" process of exhaustion marked an advance in lamp manufacture second only to the introduction of the cellulose filament. In this process rapidity is obtained by means of a special mechanical pump, permitting the exhaustion of lamps one by one. The refinement of the vacuum is accomplished by a special chemical process. We cannot pump all the gases out of the bulb, so we set a thief to catch a thief. By introducing a gas capable of combining with the residual gases remaining in bulb we render these gases innocuous and secure a vacuum of perfect insulating properties. It is this

process that has assisted more than any other one thing in the production of a successful 200–250-volt lamp, concerning which I have something to say later.

The improvement in methods since the early days is strikingly shown in the reduction in time of exhaustion of a lamp from five hours to one minute.

In photometric work the use of the revolving stand for the lamps in place of the fixed stand has greatly improved the accuracy and certainty of measurement. We now obtain the true mean horizontal candle-power of each lamp. Lamps are now readily measured to tenths of a candle, and the duplication of readings to within one-quarter of a volt by different operators made a regular result.

Generally speaking, methods and details of execution of the various processes have been carried to a high degree of perfection. By the subdivision of processes, limiting each distinct operation to one set of operators, by constant systematic and rigid inspection and testing following each operation, manufacturing results have been made far more exact; elimination of defects has been carried to a remarkable degree, and the precision of manufacture of simple mechanical products approximated to very closely.

IMPROVEMENTS IN QUALITY.

The art of lamp manufacture is not an exact one. The same methods will not always yield the same results. Slight or insignificant changes in processes produce most unexpected consequences and render it specially difficult to locate and remedy the cause of defects. The path from cause to effect is most undefined and undiscernible. Starting any improvement in a lamp, it requires a month or six weeks of testing by burning the lamps to ascertain the effects. All the processes must be exact, and the test along rigid lines, as otherwise the effect of the improvement may be masked or even discounted by other effects. Trial must be made not of one lamp, but of a large number, so as to secure the true average results, and avoid being misled by exceptional performances. In general, results are obtained only by a series of approximations.

In addition, the varieties of lamps required are surpris-

ingly large, so that to the inexactness of the art is added a great complexity of product. Taking ordinary multiple lighting lamps for central station service, and omitting all specialties, we have at least ten thousand varieties of lamps in regular demand, and if we consider all the special types of lamps, miniature and battery lamps, etc., the actual varieties number over a hundred thousand.

Still further we must note that, of any lot of lamps under manufacture, not over one-third will come out at the voltage aimed for. This means, for example, that to produce 10,000 lamps for any given exact voltage, it is necessary to make between 30,000 and 40,000 lamps, and then select from these the 10,000 lamps desired.

These several considerations may show something of the difficulties that beset the lamp manufacturer and serve to arouse our admiration of the advancement made in his art.

The most notable advance is in the matter of voltage. The early lamps were limited to 110 volts, and on alternating circuits to 50 volts. Although the 110 volt range was extended to 120 volts, lamps of these voltages were very unstable in candle-power and uncertain as to life, except at very low efficiencies, and the 50-volt lamp was the only lamp that could give fairly satisfactory results at anything better than 4 watts to the candle.

Improvements have materially changed this order of affairs. The quality of 100 to 125-volt lamps has been advanced very close to the naturally better quality of the 50-volt lamp, so that the large difference in results and performance between 50 and 100-volt types no longer exist. The 50-volt lamp was formerly twice as good as the 100-volt lamp, while at present it is but slightly more than one-quarter better. This, with the better distribution afforded from 100-volt secondaries, and better regulation obtainable with larger transformers, is rapidly causing the displacement of 50-volt lamps. In a few years the 50-volt lamp will practically be obsolete.

The tendency is all the other way, as the limits of voltage of practical incandescent lamps have been extended to 200 and to 250 volts. These 200–250-volt lamps have been very successful. Over 400,000 of them are now annually supplied

to consumers, and their use is being rapidly extended. The limitation to the use of 200-volt lamps is their low efficiency, which is 4 watts per candle or lower. At this efficiency they compare with 100–125-volt lamps of 3·1 watts per candle, giving a useful life about one-third better. In fact, they stand about halfway in results given between the 3·1-watt and 3·5-watt 100–125-volt lamps. This difference of $\frac{7}{10}$ watt per candle, or 22 per cent. more power than the 100-volt lamp for same results, weighs against the lamp, as it means reduced light capacity of dynamos and engines and increased consumption of fuel as well. The better distributing advantages of the 200-volt system have not, therefore, been sufficient to cause a change as yet in the large direct-current central stations.

It is certainly safe to expect that, with the increased demand for these high-voltage lamps (due to the economies of distribution of the 200-volt system), concentrated skill and attention will improve their quality, and bring them nearer to the naturally better results of 100-volt lamps. This would be but repeating the history of the 50-volt versus the 100-volt lamp.

The decision of what voltage to adopt for a new installation—100 or 200—is a matter of proper engineering. As far as the incandescent lamp is concerned, the choice of the systems, as between 100 and 200 volts, follows the simple law that interest on cost of copper saved by 200–250-volt system over the 100–125-volt system must be equal to or greater than the interest and depreciation on the cost of the extra capacity of machinery and copper, plus the annual cost of extra power required by 200-volt lamps over the corresponding 100-volt lamps. It has been shown by the writer (*Electrical World*, October 2, 1897) that these conditions are independent of the number of lamps and depend only on the square of the average distance from station to lamps.

Numerous inquiries are made as to the prospects of obtaining a higher efficiency lamp of this type. The 4-watt lamp is so good, it is said, why is not a 3½-watt lamp possible?

A 3½-watt 200 to 250-volt lamp is practicable. A number of such lamps have been made and sent abroad and used in special installations in this country, where they have given good results. The conditions are not ripe as yet, however, for the marketing of such a lamp. The average 200-volt station has not very close regulation, and few such stations appreciate the correct principles of lamp use. They compel their customers to buy and supply the lamps used, and as they generally sell their current by contract and not by meter, the change to the higher efficiency 3½-watt lamp would be a disadvantage to the consumer in shortening both the useful and actual life of his lamps. He would most naturally complain and condemn the lamp. To introduce a lamp under these conditions is most undesirable. Besides there are but comparatively few installations at voltages other than 220. Since all lamps cannot be made exactly to voltage, this compels the shipment of lamps of quite a range of voltage, operating directly against good life service of a higher economy lamp, as close rating in voltage is a necessity therefor. What is needed is a number of stations operating at different voltages with close regulation—supplying current on meter with free lamp renewals. A higher economy 200-volt lamp might then be introduced and tried with something like fair results.

These conditions will gradually grow and the 3½-watt lamp with them. In the meantime we may look for the introduction of lamps between 4 and 3½ watts economy. One large station has already arranged for a supply of 3·8-watt lamps on its 200-volt circuit, and it is possible that this economy will supplant the 4-watt type.

In the economy or efficiency of 100–125-volt lamps the advance has been made from 5 and 6 watts to 3 watts per candle. Surprise is frequently expressed that a higher economy than 3 watts has not been made and put in service. This surprise is natural, but shows a lack of understanding of the meaning of efficiency. It is true that the so-called 3·1-watt lamp has been on the market for some years, but what was the early 3·1-watt lamp? It was a lamp so made as to consume 3·1 watts per candle of light at the start. In a few

hours it became a 3½-watt lamp and ended a short and inglorious life at below 5 watts to the candle. Now a 2½-watt lamp can be obtained to-day that will give as good results as these early 3·1-watt lamps. Fortunately, however, customers have grown to appreciate good maintenance of candle-power, and have learned that it is the average efficiency of a lamp and not its initial efficiency which is the proper measure. By the test of average efficiency for the shortest period of life acceptable to-day—400 hours—there is as yet no full 3-watt lamp, the average being for the best lamps to-day about 3¼ watts per candle.

It is by the comparison of average efficiencies that we can best note the improvement in lamp quality. The greatest advance has been along this line, *i. e.*, the increase in average efficiency. The early 3·1-watt lamps had an average efficiency of about 3·8 watts per candle, and even below 4 watts, if we reckon results for the long period lamps were then continued in service. To change from 3·8 to 3¼ watts per candle marks, therefore, a most decided progress. This has been accomplished not only by improvements in manufacture, but also by the education of lighting companies to accept a shorter period of service from their lamps, and renew them frequently instead of permitting them to burn until broken.

Close and uniform rating is one of the chief essentials for a lamp, and a distinct advance has been effected in this respect. Early conditions with extreme voltage variation and the absence of meters rendered it perhaps redundant to have close candle-power and watt limits. This is a noteworthy instance where refinement of service conditions has made refinement of product a necessity. Again the early installations were all too largely established at some so-called standard voltage, 52, 104 and 110. The well-known inexactness of lamp manufacture as to voltage was far worse then than now, so that to ship his entire product the manufacturer naturally gave out quite an assortment of voltages. Since that time the importance of distributing installations at various voltages has been preached and practised, and the overcrowding of voltages like 104 and 110 somewhat relieved.

The adoption of a common standard of candle-power among manufacturers has likewise assisted. The time when each manufacturer had a candle-power standard of his own has passed. The leading American companies are to-day rating their lamps by the English parliamentary standard, taking the mean horizontal candle-power of each lamp when rotated at about 180 revolutions per minute.

The leading makers now photometer each and every lamp, and the practice of photometering a few and picking out the remainder by the eye is past, or continued only by the small and incompetent factories. The result is that lamps are to-day regularly supplied by the reliable manufacturer tested to the quarter of a volt, no lamp varying more than 1 candle above or below its rating, nor more than 6 per cent. above or below its rated wattage when tested at marked voltage.

This close and uniform rating has a most marked effect in improvement of the service the lamps give. With close candle-power and total wattage rating, their ratio, the watts per candle, is fixed exact. This means that all the filaments burn at exactly the same temperature and strain. It is quite evident that evenness of this temperature or strain will materially increase evenness of results in the life and maintained candle-power performance.

Let me refer again to the subject of so-called standard voltages. Although, as stated, there has been some relief from overcrowding these voltages, conditions are as yet far from perfect. Generally speaking, customers who remain at such voltages as 104 or 110 or 220 will invariably get the poorest lamps of whatever make they may purchase. This is a fact that cannot be too generally known. There are more than three times as many 110-volt lamps used to-day than are made. This means that the average customer who orders 110-volt lamps gets lamps marked 110, but really of some other voltage (either 107, 108, 109, 111, 112 or 113). There is no virtue in 104, 110 or 220, and the wise central station manager is he who changes his voltage to some special point, as, for example, 107 and 108, or 113 and 114, 117 and 118, 122 and 123, 208, 212, 230, 240, etc. Such

changes can be and have been made with comparative ease even on the largest installations.

The standard lamp of this country is the 16 candle-power lamp—in Europe the 8. In the last two or three years the demand for lamps of lower candle-power, 10, 8, 6 and even 4, has grown very large. This has been due to enforced competition for residence lighting, to the adoption of meters and to sign and decorative lighting. As a general principle in lighting, a number of small units can be distributed to give a better illuminating effect than an equivalent candle-power in larger, and, therefore, fewer units. Thus, sixteen 8 candle-power lamps distributed will give better results than eight 16 candle-power lamps. For many locations a 16 candle-power lamp is too large a unit. Electric light must compete with gas, which is quite largely used turned down. These are some among many reasons why the lower candle-power lamps, such as the 8 candle-power, should be more largely used and perhaps become the standard in place of the 16. The difficulty is that an 8 candle-power lamp cannot be made which at the same efficiency will give results equal in either life or maintained candle-power performance to the 16 candle-power. This is due to the naturally thinner and more delicate 8 candle-power filament. This results in the use of 8 candle-power lamps of lower economies than that of the 16 candle-power in use, unless shorter life and reduced candle-power performance are to be accepted. The alternative of shorter life could be adopted to advantage by many central stations who to-day retain their 16 candle-power lamps too long in service.

The quality of the 8 candle-power lamps, formerly very poor, has, however, in the last two years been materially advanced, so that it is not much below 100 hours short of the 16 candle-power lamp in useful life. This is under perfect voltage conditions. As in service such conditions are but seldom realized, 8 candle-power lamps will not appear to quite such advantage.

In physical respects the modern lamp appears to most marked advantage in comparison with the early types. The bulbs then blown free-hand, of varying sizes and

PLATE I.—Types of the different styles of lamp bases.

1—Base Edison night lamp.
2—Base Thomson-Houston night lamp.
3—Base Westinghouse night lamp.
4—Edison Swan base (brass).
5—Edison Swan base (porcelain).
6—Base candelabra lamp.
7—Base miniature lamp.
8—Base series lamp (bottom cut out).
9—Bernstein base.
10—Schaeffer base.
11—Fort Wayne Jenny base.
12—Loomis base.
13—Hawkeye base.
14—Mather or Perkins base.
15—Brush Swan base.
16—United States base.
17—Westinghouse base.
18—Thomson-Houston base (porcelain).
19—Edison base.

shapes, are now replaced by the moulded bulb of exact size to the die. The long concave neck has given place to the short-neck straight-sided bulb of less obtrusive and more practical character.

The filaments have been symmetrically shaped, giving an artistic effect and increasing the spherical candle-power (with the same mean horizontal). The filaments are anchored or so supported that there is no drooping. The inside parts are all accurately gauged and placed, so that each lamp is the exact counterpart of any other in respect to all its details.

In early days every manufacturer of a new system had to have a special socket and lamp base. There were no less than thirteen different types of bases in this country alone, and in Europe about as many more varieties. This naturally multiplied the types of lamps very greatly, and was a great burden to both manufacturer and customer. Simplification has progressed so far already in this matter that there are to-day in this country practically only three bases, the Edison, Thomson-Houston and Westinghouse. The tendency is strongly towards a still further reduction to one, *i. e.*, the Edison. This is a pure case of survival of the fittest. The Westinghouse base and socket have, as is well known, the grave faults of poor and uncertain contacts, which are aggravated by use. The Thomson-Houston, while perhaps a good socket, is one of the most troublesome of bases. The screwing of a Thomson-Houston base in its socket acts to tear it apart (the reverse of the Edison, where the result is a binding action holding the parts together); the contacts are very close together, and are liable to arcing and short-circuiting. The Thomson-Houston base is also complex and expensive. It has three or four parts to two for the Edison, and costs about 1 cent a piece more. On this account there is an extra charge of 1 cent per lamp on all Thomson-Houston base lamps, and this is operating effectually and gradually to render the Thomson-Houston base obsolete. This change is helped by an adapter, furnished by the General Electric Company, which, by simply screwing in the socket, changes it from a Thomson-Houston to the Edison type.

This change to one standard base will require some time, however, as there are still a large number of both Westinghouse and Thomson-Houston in use, and the change of the Westinghouse requiring a complete replacement of sockets is costly and troublesome. Roughly estimated, the proportion of the different sockets in use in the United States is as follows:

	Per Cent.
Edison	55
Thomson-Houston	25
Westinghouse	15
All other types	5

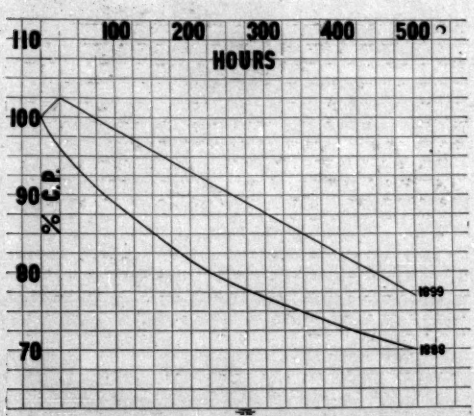


FIG. 1.—Curves showing ten years' improvement in candle-power performance of 3·1-watt incandescent lamps.

The only real objection to the Edison base was the live contact exposed by the portion of the shell part of base extending outside of socket. This has been corrected by shortening the shell, so that socket entirely covers base. The use of porcelain marks the greatest improvement in bases—the Thomson-Houston base is now made entirely of porcelain with metal contacts.

The improvement in average efficiency to which I have

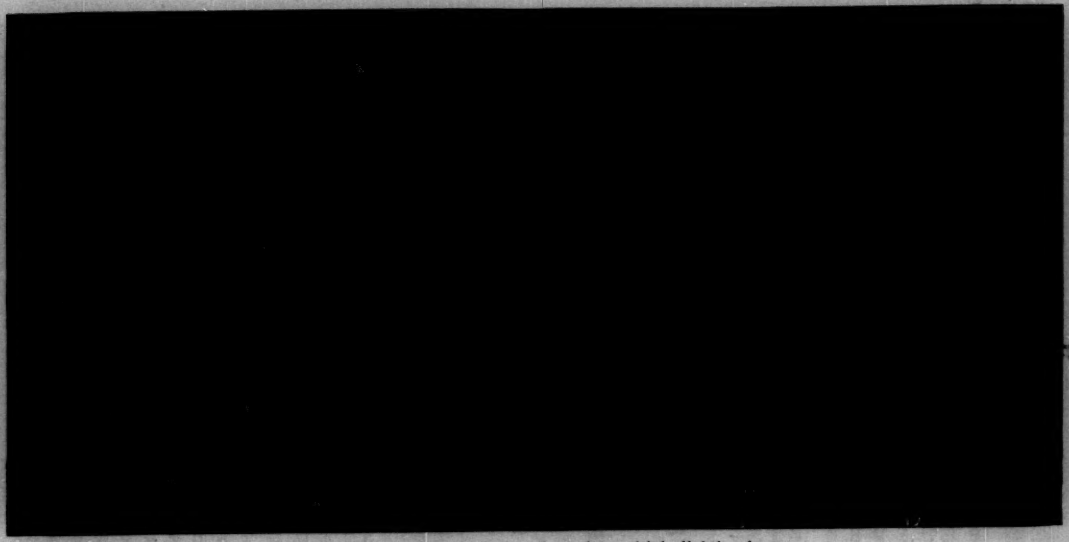


PLATE II.—Types of standard and special multiple lighting lamps.

1—Lamp for buoy lighting.
2—European lamp.
3—Round bulb lamp.
4—10 c. p. 100-125-volt lamp.
5—Stereopticon lamp, 50 c. p.
6—Tubular lamp.
7—Resistance lamp.
8—4 c. p. 100-125-volt lamp.
9—Diving lamp.
10—Standard 16 c. p. 100-125-volt lamp.
11—Standard 16 c. p. U. S. N. cruiser lamp, 80-volt.
12—Standard 32 c. p. 100-125-volt lamp.
13—Standard 100 c. p. lamp.
14—Standard 50 c. p. 100-125-volt lamp.
15—Old style lamp. Free blown bulb.
16—10 and 16 c. p. 50-volt lamp.
17—Reflector lamp.

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PLATE III.—Types of miniature lamps.

SPECIAL SERIES LAMPS.

1—8 c. p.
2—5 c. p.
3—3 c. p.
4—1 c. p.

U. S. N. LAMPS.

5—Binnacle lamp.
6—Instrument lamp.
7—Instrument lamp.
8—Torpedo lamp.

9—Kinetoscope lamp.
10—Bicycle lamp.
11—Telephone lamp.
12—Telephone lamp.
13—Watch charm lamp.

DENTAL LAMPS.

14—
15—
16—
17—Pea lamp.
18—Surgical lamp.

MICROSCOPE LAMPS.

19—
20—
21—4 c. p. spherical lamp.

FLAT LAMPS.

22—4 c. p.
23—1 c. p.
24 Miner's lamp.

BATTERY LAMPS.

25—½ c. p.
26—1 c. p.
27—2 c. p.
28—3 c. p.
29—4 c. p.
30—6 c. p.
31—Theatrical.
32—Stick pin lamp.

MULTIPLE CANDELABRA LAMPS.

33—Style A.
34—Style B.
35—Style D.
36—Style E.
37—Style F.
38—Battery lamps for steam railway carriage lighting.

SERIES CANDELABRA LAMPS.

39—Style A.
40—Style B.
41—Style C.
42—Style D.
43—Style E.

referred concerns the candle-power performance. Such a notable advance has been made in this respect, however, that it will be of interest to speak of it again in another way.

In diagram, *Fig. 1*, we have two curves—the lower one shows the candle-power performance by hours of burning for the early 3·1-watt lamps, and the upper one the present lamp of same make. The early lamp reaches 80 per cent. of 16 candle-power, the comparison basis, at 200 hours, and the present lamp at 450 hours.

Such lamps as give a result like these early ones no station could afford to-day to use, at less than half the price of the present best ones.

A word or two about the improved methods of supply. Lamps are now purchased by all large users on what is known as the future delivery system. On this plan the customer places his order for his year needs, specified as to types desired, with the manufacturer, and lamps are shipped to him thereon during the year as he needs them. This system has proved of inestimable value to both manufacturer and customer. It permits the manufacturer to run his factory uniformly through the year, avoiding the old conditions of heavy rush production in the fall and winter and the reduced output of summer. It allows the accumulation of the requisite stocks for prompt shipments during the rush season. It guides the manufacturer as to the classes and types of lamps desired and the number of each, and thus enables him to avoid producing dead stock. In early days the dead stock accumulated through lack of knowledge of requirements was tremendous. Many thousands of lamps that could not be sold had to be annually broken up.

The economies of this future delivery system secure the customer a special price. It is not too much to say that the future delivery system is the mainstay of the lamp business to-day. It would be impossible to supply the high-grade closely-rated product sold to-day at the present low prices without future delivery orders from the consumers.

[*To be concluded.*]

CHEMICAL SECTION.

Stated Meeting, held January 16, 1900.

RACEMISM.

By Robert Hart Bradbury.

I. HISTORICAL.

In 1824 Liebig completed in Gay-Lussac's laboratory an investigation of the fulminates. Shortly before, Wöhler, working in the laboratory of Berzelius, had brought to a close a series of analyses of the cyanates. When comparing his results with those of Wöhler, Liebig was surprised to perceive that the composition of the two classes of substances was the same. At first he assumed that Wöhler's results were incorrect and carefully repeated the latter's work, without however detecting any error. Thus Wöhler and he were driven to admit that it was possible for two substances of the same composition to possess absolutely different properties, but this conclusion was not at once admitted by other chemists. Then followed, in 1825, the discovery by Faraday of benzene, erroneously supposed to be identical in composition with ethylene. Tartaric acid had been known since 1769, when Scheele, and after him Retzius, obtained it by the decomposition of calcium tartrate by sulphuric acid, and racemic acid had been discovered by Kestner, and investigated in 1826 by Gay-Lussac, who found that it required the same amount of alkali for neutralization as tartaric acid, and in 1830 by Berzelius, who satisfied himself of the complete identity of the two in composition and supposed, incorrectly, that they possessed the same molecular weight. In his account of the progress of chemical science during the year, he admits the existence of the phenomenon and proposes for it the name now in use.* He refers to the work of Liebig and Wöhler, and of Faraday, to the results of Clarke in phosphoric and metaphosphoric

*Berzelius, *Jahresbericht*, xi, 44 (1831).

acid, where the supposed identity of composition was erroneous, to his own investigations of the two stannic acids, and finally to racemic acid, which he considered a decisive example. He suggests, as an explanation, that compounds differing in this way, since the atoms are the same in number and kind, must possess different atomic arrangement, and adds that the discovery of Mitscherlich, that substances may contain different atoms and still crystallize in the same way, must now be supplemented by the fact that the same atomic complex may give rise to different crystallizations if the arrangement of the atoms is different. It is remarkable that the decisive example which caused Berzelius to admit the possibility of isomerism and to suggest a structural explanation should have been a case of that subtle kind where the explanation fails, and a spatial extension of the doctrine of atomic linking is necessary.

In 1848 Pasteur published his beautiful researches on the tartaric acids. The passage in which he announces his chief result is so germane to our present subject and of such great historical interest that I shall translate it.*

"I found that all the tartrates crystallize with hemihedral faces. In studying the double racemate of sodium and ammonium I noticed that these faces were differently placed in different crystals, sometimes at the right, sometimes at the left. I separated with care the right-hand from the left-hand crystals and observed the solutions separately in the polariscope. With surprise and pleasure I saw that the solution from the right-hand crystals turned the plane to the right, that from the left-hand crystals to the left. Thus, starting from racemic acid I obtain in the usual way the sodium ammonium racemate, and the solution deposits, after some days, crystals which are alike in appearance and possess the same angles and yet, most certainly, the molecular arrangement of the two must be entirely different. The two species of crystals are isomorphous with each other and with the corresponding tartrates; each is the mirrored

*Pasteur, *Annales de Chim. et de Phys.*, third series, xxiv, 442; xxviii, 50. Also *Comptes Rendus*, xxiii, 535; xxix, 297; xxxi, 480.

image of the other. In fact, if, in both species, I suppose the hemihedral faces prolonged until they meet, I obtain two tetrahedra which are unsuperposable, and one of which is the reflection of the other. It was very important to investigate if, in the crystallization of the substance, there was deposited for each dextro-rotatory molecule, a lævo-rotatory molecule. Experiment leaves no doubt that this is the case.

"When the crystals are simply dissolved, without any selection, the solution is inactive, and the fact that equal quantities of the two salts are deposited is clear from the inactivity of the mother liquor." He prepared dextro- and lævo- neutral sodium tartrates from the corresponding crystals of the sodium ammonium salts, and finally obtained from each sodium ammonium salt its corresponding barium salt, and, decomposing these with sulphuric acid, prepared dextro- and lævo-tartaric acids.

In the first paper the identity of the dextro-acid with ordinary tartaric acid is expressed with reserve. Having obtained from Kestner, its discoverer, a large quantity of racemic acid, he returned to the subject in a paper published two years later, and established beyond doubt this conclusion, as well as the extraordinary resemblance between the dextro- and the lævo-acid. In crystalline form the two are identical, except for the enantiomorphism already referred to. On the right-hand crystals the left-hand hemihedral faces are sometimes absent, but more commonly present in imperfect state of development. Very rarely both sets of faces are completely developed in the same crystal, so that the asymmetry is only evinced in its action on polarized light. Their density and chemical composition are identical. Both kinds of crystals are electrically excited when heated or cooled. When the dextro-crystals are cooled the end containing the hemihedral faces becomes the positive pole; when heated, the negative. This same statement applies to the lævo-crystals. The rotatory power of both is the same, but is exerted in opposite directions, and this is true for light of every wave-length, so that the rotatory dispersion of dextro-tartaric acid, studied by Biot,

is found unchanged in the solutions of the lævo-acid. The rotatory power of both is decreased with falling temperature to an equal extent. This suggested to Pasteur a curious experiment. Since the solution of dextro-tartaric acid differs from that of the lævo-acid only in the sense of the rotation, and since the amount of the rotation is decreased by cooling, it occurred to him that it might, by cooling, be transformed into the lævo-acid, which would then unite with the unchanged dextro-acid to produce racemic acid. Of course the result was negative. The possibility that racemic acid was a mixture occurred to him. With the criteria at hand at that time the distinction between mixture and compound in such an extremely subtle case was a difficult one; nevertheless, he arrived at the correct conclusion. When the solutions of dextro- and lævo-sodium ammonium tartrates are separately treated with a soluble calcium salt no precipitate is produced at once, but there appear slowly crystals of the two tartrates, which are exactly similar in the two cases. But when the solutions are mixed and then the calcium salt added, there is immediately formed a precipitate of calcium racemate, in small plates, or an amorphous powder. From this he concluded that racemic acid was a compound. Pasteur found that, in general, the two optical isomers remained combined in the various salts, and when the salts were crystallized.

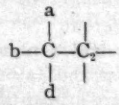
The behavior of the sodium ammonium salt was exceptional, and the only other racemate which he found to separate into the single tartrates when crystallized was the isomorphous sodium potassium salt. The determining influence of solubility and, through it, of temperature on the separation, escaped him. This is the classical case of optical isomerism, and it has been found since that many of Pasteur's statements are equally true in similar cases, and that dextro- and lævo-tartaric acids—the two antimeres* as

* This convenient term is due, I believe, to Lachmann: *Cf.* "Spirit of Organic Chemistry," p. 127. For convenience I shall also use the term enantiomorph, though it is not accurate.

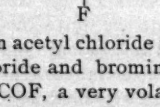
we shall call them, and racemic acid, the inactive compound of the two—are typical examples of a whole class of substances. It is now in order to inquire to what extent Pasteur's results are of general application.

II. THE NATURE OF THE PHENOMENON.

At present the discussion is restricted to those compounds which rotate the plane of polarization in uncrystallized condition, that is, when they exist as liquids or vapors, or in solution. This phenomenon has thus far been observed only among the compounds of carbon, and only in those which contain a carbon atom whose four valences are satisfied by four different atoms or radicles, an asymmetric carbon atom. A further structural condition which must be fulfilled is that at least one of the valences of the asymmetric C must be linked directly to carbon, or the molecule must contain the group

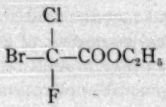


where a, b and d may be anything, so long as they are not alike and C_2— is a monovalent radicle whose carbon atom is linked directly to the asymmetric carbon atom. The simplest compound, structurally, in which optical isomerism has been observed is chlor-brom-fluo-acetic acid.



When chlor-di-brom acetyl chloride is treated with a mixture of antimony trifluoride and bromine, the fluoranhydride of the acid, ClFBrC—COF, a very volatile liquid, is produced. By the action of alcohol, the F combined with carbonyl is readily replaced by ethoxyl, yielding the ethyl ester of the acid.

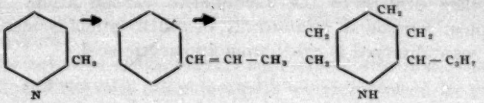
* Swarts, *Bull. de l'Acad. de Belg.*, 31, 28.



and this is easily saponified by bases. The acid is a syrupy hygroscopic liquid: all of its salts are soluble in water. The strychnine and cinchonine salts can be separated into isomers of different rotatory power, and this shows the existence of optical isomerism in the acid. By heating the sodium or potassium salt with caustic potash or soda chlorbrom-fluo-methane is obtained. If this proves to exhibit optical isomerism, it will furnish the simplest conceivable case, and we shall have to drop the second structural condition. It has not yet been investigated in this respect.

If the asymmetric combination is situated in a ring it can still produce optical isomerism, provided that the aspects which the ring presents to the two valences of the atom in question are different.

Of course, if the ring had a plane of symmetry passing through the carbon atom, the latter would not be asymmetric. Thus Ladenburg's beautiful synthesis of conine from *α* picoline and paraldehyde, followed by reduction of the product,* has shown it to be *α* n-propyl piperidine.



Emil Fischer is undoubtedly right in his contention that the proofs Ladenburg advances for the racemic character of liquid synthetic conine are quite inconclusive;† but this does not affect the fact that optical isomerism exists in the case. The doctrine of the tetrahedral arrangement in space of the atoms or radicles attached to C‡ has become one

* Liebig's Annalen, ccxlvii, 81.

† *Berichte*, xxvii, 1525, 3224.

‡ Le Bell, *Bull. de la Soc. Chimique*, second series, xxii, 337. Van't Hoff, *lb.*, second series, xxiii, 295.

of the commonplaces of chemical theory, and it is unnecessary here to do more than refer to the fact that this natural extension of the structural idea has furnished a very satisfactory explanation of the matter.* When, therefore, the structural peculiarity just noticed is present in the molecule, the existence of optical isomers is to be expected, and the two compounds are found to exhibit an astounding resemblance which extends to many of the minutest details of chemical and physical behavior. The most conspicuous difference is the rotatory power, which is equal in amount but opposite in sense.† Differences exist in their relations to

* The stereo-chemistry of nitrogen cannot be discussed in the present paper. But it is desirable to point out that very recent results indicate that the presence of pentavalent nitrogen united to five different radicles can produce molecular asymmetry quite analogous to that conditioned by the carbon atom. Eight years ago Le Bel announced the optical activity of methyl-ethyl propyl-isobutyl ammonium chloride

$$N(CH_3)(C_2H_5).(C_3H_7)(C_4H_9)Cl.$$

His results have recently been sharply questioned by Marckwald and von Droste-Huelshoff (*Berichte*, xxxii, 560 (1899)), but Le Bel has replied, giving details and maintaining the correctness of his observations (*Comptes Rendus*, cxxix, 548). Still more recently Pope and Peachey have announced the preparation of dextro- and lævo-benzyl-phenyl-allyl-methyl ammonium iodide and bromide, *e. g.*,

$$N(CH_2C_6H_5)(C_6H_5)(C_3H_5)(CH_3)I.$$

The results indicate that the pure antimeres have equal and opposite rotatory power, so that so far the analogy of the phenomena to those of the asymmetric carbon atom is complete (*Jour. Chem. Soc.*, xv, 192).

† The subject of the variation in rotatory power with the conditions under which the substance is placed lies outside the scope of the present paper. But it is necessary to remark that in order for the antimeres to exhibit equal and opposed rotatory power they must be rigorously under the same conditions, and, so far as we know at present, interpolations and especially extrapolations from observations made at other temperatures and concentrations are absolutely inadmissible, for with the variation of these conditions the rotatory power changes its amount and even its sign. The character of the solvent and the presence of various inactive substances in the same liquid also affect it profoundly. The effect of the solvent ceases to be surprising when we consider the very different conditions in which the same dissolved substance may exist in different liquids. It is not astonishing that the ions should rotate differently from the undissociated molecule, and this in turn from the double molecule. Here are some of the facts, mostly from the extremely interesting paper of Walden (*Berichte*, xxxii, 2849 (1899)). The rotation of aqueous solutions

other asymmetric substances. Thus, if the substances in question are acids they will combine with the same asymmetric base with different speeds, and the two salts will possess different solubilities.

The enantiomorphous crystallization of the antimeres has been erected into an article of faith, partly because of the simplicity and beauty of the conception and partly because it harmonizes well with modern views of crystalline structure.* But the facts are completely opposed to such a generalization. It has just been noticed that even in Pasteur's typical case the enantiomorphism is only of occasional occurrence. And, over the whole field, the number of optical isomerides which do not crystallize enantiomorphously, and must be ranked as exceptions, is greater than that of those which obey the rule.† It is, of course, possible to assume that all of the innumerable exceptions will be found to be enantiomorphous, but this is a most inadmissible procedure. Since the optical activity of the two antimeres is equal and opposite, it is clear that a solution containing both in equal quantity will produce no rotation. The substance containing both in equal quantities, merely mixed, is called the inactive mixture. It is an ordinary mechanical mixture, and derives its importance from the

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of ordinary d-tartaric acid becomes less with increasing concentration, and very strong solutions are lævo-rotatory. So, also, is the anhydrous substance. Dilute solutions in water of ordinary natural malic acid are lævo-rotatory, but with increasing percentage the activity decreases, the solution becomes inactive and finally dextro-rotatory. The same malic acid is lævo-rotatory in water, acetone, acetaldehyde, isobutyl alcohol, acetophenone and most other solvents, but dextro-rotatory in benzyl alcohol and in mixtures of the latter with benzene and carbon disulphide. Its strong solution in anhydrous formic acid is feebly lævo-rotatory at ordinary temperatures, and feebly dextro-rotatory at 0°. Fused malic acid is lævo-rotatory at moderately elevated temperatures, but at about 40° the optical activity changes sign, and with further cooling the substance becomes increasingly dextro-rotatory. It will be seen from these facts that the decision which acid to name dextro- and which lævo- is not so exceedingly easy as it might appear at first glance. Fortunately the fundamental contention that *under the same circumstances* the optical activity of the two antimeres is equal and opposite remains entirely undisturbed.

* Even van't Hoff falls into this error. "Vorlesungen über Theoret. Chemie." ii, 98 (1899).

† Walden, *Berichte*, xxix, 1693.

frequency with which it is obtained in chemical operations. The enantiomorphs being perfectly symmetrical, their chances of being produced in a symmetrical synthesis are equal. Hence the products of a synthesis in which a carbon atom becomes asymmetric are inactive, and the isomerism is only evident when the antimeres are separated.

The existence of a racemic compound of the two antimeres appears to be a general phenomenon. This is perfectly distinct from the mixture, being a homogeneous chemical substance, whose density, crystalline form, solubility, etc., are different from those of the antimeres. It is universally held that it possesses double the molecular weight, racemic acid, for example, being written $(C_4H_6O_6)_2$, and corresponding formulas set up for the racemates, but it is impossible to find any basis for this belief. It is, in fact, impossible to determine the molecular weight of a racemic compound, for our methods of determining molecular weight are valid only for solutions, gases and vapors, and when applied to racemic compounds, the result obtained always corresponds to the simple molecular weight of one antimere, so that we must assume that they dissociate into the enantiomorphs when vaporized or dissolved.

The same conclusion is arrived at from the study of the physical properties of their solutions and from the fact that solutions of the antimeres exhibit no evolution or absorption of heat when mixed.*

The question regarding the existence of racemic compounds in the liquid state is entirely an open one, and I know of no facts which forbid our making the assumption, tentatively at least, that they exist only in the solid state.

Küster† has attempted to show that the solubility relations can be best explained by the assumption that the racemic compound exists in solution. But the solubility of a racemic compound is an extremely complex phenomenon and is affected by a number of factors, among which are the number of racemic molecules in the solution,

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*Jahn, "Wiedemann's Annalen," xliii, 306 (1891).

†*Berichte*, xxxi, 1847 (1898).

the extent to which the racemic molecules are electrolytically dissociated and the extent to which the antimeres are ionized. Further, if one works with the pure racemic compound, and the antimeres are not present as solid phases, the possibility of supersaturation with respect to them must be kept in mind. Such considerations, therefore, as Roozeboom has remarked, are valid only for very slightly soluble substances.

The recent death of the young Italian chemist, Andreocci, left unfinished an interesting investigation of the triboluminescence of racemoid and antimeric forms.*

Triboluminescence is simply the flash of light which is emitted at the time the crystalline structure is destroyed, either by grinding or splitting. The work must be done in complete darkness. The conclusions cannot be regarded as of universal validity, since they were obtained purely by experiments on the santonine derivatives and elsewhere different relations may prevail. The general results are these. Optically active substances are not necessarily triboluminescent; some exhibit the phenomenon intensely, others feebly, others still, not at all. All the well-characterized antimeres examined were triboluminescent, and the isomers are just as similar here as they are in all other respects, giving out exactly the same kind of light when crushed. The light is yellowish-green or emerald green. Racemic compounds never exhibit the phenomenon. Partially racemic compounds may be triboluminescent.†

Regarding the conditions under which the antimeres unite to produce the racemic form, some generalizations are at hand. It is clear thermodynamically that if the isomers unite with evolution of heat, their compound will be decomposed by heat and that they will reunite on cooling, while if they unite with absorption of heat the reverse will be true. Many cases of both are known. Further, a racemic compound is simply a double salt, though a double salt of a very special kind, and the views that have proved useful in

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* *Gazz. Chimica Italiana*, xxix, 519.

† The phenomena of partial racemism will be discussed later.

dealing with double salts in general are applicable here. For some time it has been evident that in a system in which a double salt exists only as solid phase the direction of the charge at the inversion point can be foretold if we know the amounts of water of crystallization in the double salt and in the component single salts. It is found that if the double salt is poorer in water than the single salts taken together, it is formed from the single salts on heating; if it contains more water, the reverse is true.* This is just as true of racemic compounds as it is of other double salts.† Thus racemic ammonium malate separates at 73° into the dextro and lævo isomers. Below this temperature the racemic form is stable; above it, the separate salts. Now the antimeres are anhydrous and the racemic form, if we use the conventional double molecule, crystallizes with two molecules of water. Hence the reaction is

$$(C_4H_5O_5NH_4)_2 2H_2O = d.C_4H_5O_5NH_4 + l.C_4H_5O_5NH_4 + 2H_2O,$$

the change taking place with elimination of two molecules of water. On the other hand, when a mixture of the dextro- and lævo-sodium ammonium tartrates is heated to 27° the racemate is produced, thus

$$d.C_4H_4O_6NaNH_4.4H_2O + l.C_4H_4O_6NaNH_4.4H_2O = (C_4H_4O_6NaNH_4)_2 2H_2 + 6H_2O,$$

six molecules of water being set free as a result. It seems that the production of the racemic form is accompanied in general by a decrease in volume. This statement is called Liebisch's rule, and is expressed in the following form:

"Die Verbindung der optisch isomeren Körper zu einer krystallisierten racemischen Verbindung findet unter Contraction statt." Walden concludes, from the examination of a large amount of material, that it is applicable to all cases thus far studied.‡

There is at present no relation connecting the melting point of a compound with those of its constituents, and this

* Bancroft, "The Phase Rule," p. 180 (1897).
† Van't Hoff, *Berichte*, xxxii, 857 (1899).
‡ *Berichte*, xxix, 1693 (1896).

is true also of the compounds composed of optical isomers. The racemic derivative is simply a new form of matter, with its own melting point, which may be higher or lower than that of its constituents.

It is to be remembered that the antimeres have the same melting point. The cases mentioned by Walden in which the racemic form has the same melting point as its two constituents are certainly very surprising, but they can hardly be more than accidental. The most natural supposition is that these substances were in reality mix-crystals, or solid solutions, in which case they would possibly, though not necessarily, behave in this way; but this assumption is contradicted by the fact that they possessed a distinctly different crystalline form from that of the antimeres. Melting point determinations of these substances are much complicated by the possibility of change of crystalline form on heating—these compounds seem to exhibit polymorphism with unusual frequency—and, on the whole, as we shall see, the determination of the melting point has little or no diagnostic value.

The phenomena when the racemic form is produced from the antimeres, or separates into them, are nearly those of the formation and separation of double salts. The chief difference is that the precisely equal solubility of the two isomers at all temperatures very greatly simplifies matters. Systems in which a double salt is possible will, in general, contain three components, the two single salts and the solvent, usually water.* Five phases will completely determine the system; three solid substances, solution and vapor, for example. For our purpose the complications introduced by the presence of different amounts of water of crystallization can be neglected, and the only solid phases we need consider are the two component salts and the double salt

* The Gibbs Phase Rule and the associated deductions furnish the only point of view from which the passage from the antimeres to the racemic form and reversely can be properly regarded. It is, of course, impossible to discuss this extensive subject in the present paper. The only complete account of the matter, fortunately an excellent one, is by Bancroft—"The Phase Rule" (Ithaca, 1897).

formed from them. The phase rule informs us that the presence of these three solids in equilibrium with solution and vapor will occur at an inversion point. An inversion is a state of things analogous to the equilibrium of ice, liquid water and water vapor. The phases can only coexist in equilibrium at one particular temperature, and the addition or subtraction of heat will produce no alteration in temperature until it has brought about the disappearance of one or more of the phases. When, for example, the double salt schönite is cooled slowly in contact with its saturated solution, the thermometer remains stationary at — 3° until the reaction:*

$$K_2Mg(SO_4)_26H_2O + H_2O = K_2SO_4 + MgSO_47H_2O$$

is complete, *i. e.*, until the solid phase schönite has disappeared. And when the mixture of potassium and magnesium sulphates is again allowed to heat, the thermometer again remains stationary until the reverse change.

$$K_2SO_4 + MgSO_47H_2O = K_2Mg(SO_4)_26H_2O + H_2O$$

is over, and the two single salts as solid phases have disappeared. It will be perceived that the thermometer furnishes one method of locating the inversion point. Another is given by the dilatometer. This consists essentially of a bulb ending in a capillary tube. The bulb contains an intimate mixture of the two component salts, or else the powdered double salt, and the interstices of the powder and a portion of the capillary tube are filled with some liquid which is assumed to have no effect on the process, *e. g.*, petroleum. If the apparatus is very slowly heated there will be the usual expansion, shown by a slow rise of the oil column, but when the point is reached at which the double salt splits up, or is formed, as the case may be, a change of volume due to the chemical reaction in the bulb, a change of a higher order of magnitude than the thermal volume changes, will appear. This may be either positive or negative, and its appearance locates the temperature in question.

* Van't Hoff, *Vorlesungen über Theoret. Chem.*, i, 76 (1898).
Bancroft, "The Phase Rule," p. 165 (1897).

In the practical use of this apparatus it must be remembered that the impossibility of heating the system above the inversion point, until the change has occurred, refers only to the impossibility of the existence of the same system in stable equilibrium on both sides of the inversion point. It is true without modification of one physical change, the melting point of a solid, for a solid cannot be heated above its melting point, but in chemical changes the slowness of the change and the possibility of unstable equilibrium complicate matters, and the statement applies only to the ideal limiting case where the heat supply is so slow that all of it can be consumed by the chemical change. Nevertheless, if the heating be sufficiently slow, the dilatometer will show a very noticeable maximum of alteration of volume in the neighborhood of the inversion point. Then the temperature in question can be accurately fixed in a somewhat different way. Let us assume that the double salt is formed from its constituent single salts in presence of the saturated solution with absorption of heat and separation of water of crystallization. Then it will be produced from them on heating, and below the inversion point the two single salts will be in stable equilibrium with the solution as solid phases, above it the double salt. If the proper precaution to avoid supersaturation with respect to the double salt is taken, its formation will begin at the inversion point. But since the change occurs slowly it will in general be possible to heat the system containing the three solid phases above the inversion point. Here the system cannot be in equilibrium, and the change of the single salts into the double salt will occur. In the same way it will be possible to cool the system below the inversion point, but here the direction of the change will be reversed, and the double salt will decompose. For the sake of definiteness let us make the purely arbitrary assumption that when the double salt is produced expansion takes place. Then it is evident that at any temperature above the inversion point the level of the oil will rise, at any temperature below it will sink. These changes are easily distinguished from thermal volume changes, since they continue when the

apparatus is maintained at a fixed temperature, which, of course, is not the case with ordinary expansion and contraction. Practically, therefore, the inversion point is the point at which the volume alteration changes its sign.

Much of our knowledge of this subject is due to Van't Hoff, and we owe to him also the proof that the formation and separation of racemic compounds are in all respects to be classed with ordinary double salt phenomena.* The reaction investigated was the classical one, the transformation of dextro- and lævo-sodium ammonium tartrates into the racemate:

$$2C_4H_4O_6NaNH_4.4H_2O = (C_4H_4O_6NaNH_4)_2 2H_2O + 6H_2O.$$

Since the racemate is formed with separation of water, we should expect it to be produced on heating. Little had been done since the time of Pasteur to clear up the nature of the change. Bichat had speculated obscurely about the influence of "germs" from the atmosphere—the "germs" in question being minute crystals or dust promoting crystallization—and had shown that in sealed tubes the phenomena were irregular. Wyrouboff,† in a remarkable paper, had pointed out clearly that temperature was the determining factor, and was so through its different effect upon the solubility of the racemate and the single tartrates. He remarks that if one evaporates the solution of the mixed tartrates in the usual way, that which crystallizes will be the substance least soluble at the temperature. Above 28° the racemate is always obtained; below, the single tartrates.

The only function of the "germs" is to exclude supersaturation, which may play a disturbing rôle when one works in sealed tubes. In the work of Van't Hoff and Van Deventer, the change in question was, for the first time, studied from the same standpoint as the behavior of other double salt reactions. The results which interest us are these:

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* Van't Hoff and Van Deventer, *Zeitschrift für Physikal. Chem.*, i, 173 (1887).

† *Comptes Rendus*, cii, 627 (1886).

(1) Powdered sodium ammonium racemate, mixed with water to a thin paste under 27°, solidifies completely to a dry mass of the single tartrates. Over 27°, this does not occur.

(2) The finely powdered mixture of the two tartrates remains completely unaltered under 27°. Above this temperature the formation of the racemate occurs and the free water produces liquefaction.

(3) The inversion temperature can be more accurately estimated by the dilatometer. Between 26·7° and 27·7° there is a great expansion, partial liquefaction occurs and the monoclinic crystals of the racemate can be plainly seen.*

[*To be concluded.*]

CORRESPONDENCE.

WHAT IS PARIANITE?

A CORRECTION BY DR. ENDEMANN.

Editor of the Journal of the Franklin Institute.

DEAR SIR:—I desire to correct a misstatement which appears in Dr. Keller's contribution to the discussion of Professor Peckham's paper in the March impression of the *Journal*. This error is due either to my misunderstanding of a question or to a misapprehension on the part of Dr. Keller.

I understood him to ask whether I had made any efforts to isolate compounds of definite composition from the petrolenes, and answered negatively.

As the report of the meeting reads, it would seem that I had made no efforts to isolate compounds of definite composition from asphalt generally.

As it is, I have neglected the petrolenes altogether, these being the subordinate portion of asphalt. Asphalt differs from petroleum by reason of the predominating presence of solids. In examining the solids of asphalts, I have done all my work, and have made not only efforts to isolate, but I think I have isolated, compounds as far as it is possible at the present time, for I have never yet been able to produce a crystalline compound.

Very truly yours,

H. ENDEMANN.

NEW YORK, March 14, 1900.

*There is here no conflict with Liebisch's rule. It is the water split off which produces the expansion.

BOOK NOTICES.

Leçons sur l'Electricité, professées à l'Institut Montefiore. Par Eric Gérard, Directeur de l'Institut électrotechnique Montefiore. 6e édition, 2 volumes grand in-8. 1899-1900. (Paris: Librairie Gauthier-Villars. Prix de chaque volume: 12 francs.)

The circumstance that a work has reached its sixth edition within a few years is, of itself, fairly good evidence that it has a *raison d'être*. Aside from this generalization, the work is fairly representative of the present theory and practice of electricity. The work is printed in two volumes, the first devoted to the theory of electricity and the modes of its production; and the second to the industrial applications of electricity based on the mechanical, luminous, calorific and chemical effects of the electric current.

The second volume is the subject of this notice. The author appears to have omitted nothing in this edition that is necessary to bring his work up to date. W.

Encyclopédie scientifique des Aide-Mémoire. Small 8vo. Paris: Gauthier-Villars. 1899. Price, per volume, 2.50 francs in paper; 3 francs in cloth.

Since the last notice of this valuable series of hand-books for engineers, the following volumes have been issued from the press. The entire series forms an exceedingly compact body of reference literature on almost every scientific and technical topic now engaging attention. The authors are generally men of note in their specialties, and their works appear to be well brought up to date. W.

Seyrig (*T.*), Ingénieur-Constructeur. Statique graphique des systèmes triangulés. I. *Exposés théoriques*. II. *Exemples d'applications*.

Vigneron (*E.*), ancien Professeur à l'École supérieure d'Électricité, Ingénieur au Service technique de la Cie générale des Omnibus, et *Letheule* (*P.*), Ingénieur à la Cie Thomson-Houston. Mesures electriques. *Essais de laboratoire*.

Gouré de Villemontée, ancien Élève de l'École Normale supérieure, etc. Résistance électrique et fluidité.

Minet (*Adolphe*), Ingénieur, Directeur du journal *L'Electrochimie*. Analyses électrolytiques.

Lefèvre (*Julien*), Professeur à l'École des Sciences et à l'École de Médecine de Nantes. La liquéfaction des gaz et ses applications.

Niewenglowski (*G. H.*), Préparateur à la Faculté des Sciences de Paris, Directeur du journal *La Photographie*. Applications de la Photographie aux Arts industriels.

Dariès (*Georges*), Conducteur au Service des Eaux de Paris. Calcul des canaux et aqueducs.

Pozzi-Escot (*M. E.*), Chimiste, Rédacteur au "Praticien industriel," etc. Analyse chimique qualitative.

Laurent (*P.*), Ingénieur au Polygone du Hoc. Résistance des bouches à feu.

Leloutre (*G.*), Ingénieur civil. L'échappement dans les machines.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, March 21, 1900.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 21, 1900.

Vice-President THEO. D. RAND took the chair at 8 o'clock P.M.

Present, 42 members and visitors.

Additions to membership since last report, 29.

A communication was read from Mr. Howard B. French, accepting election to the Board of Managers.

Mr. A. L. Hahl, of Chicago, exhibited and described his pneumatic time-controlling and distributing system, illustrating the subject with the aid of one of his synchronizing master-clocks controlling a number of clock-dials connected therewith.

The Secretary, in his report, called attention to the arrangements which had been made in the interest of members desiring to visit the World's Fair shortly to be opened in Paris; also, to the total solar eclipse, to take place on May 28, 1900, and which will afford residents of the eastern portion of the United States a convenient opportunity for observation, the path of totality being in about the latitude of Norfolk, Va. It was also stated that the Physical and Astronomical and the Photographic Sections of the Institute would probably take steps, at the proper time, to arrange for an excursion of their members and of the members of the Institute generally to witness the occurrence, and probably to unite with other scientific bodies in the work of observation.

Adjourned.

WM. H. WAHL,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, March 7, 1900.*]

MR. WM. PENN EVANS in the chair.

The following reports were adopted:

Water-Heater for Range Boilers.—Adam Heller, Baltimore, Md.

ABSTRACT.—This device is designed for heating the water contained in vertical circulating boilers attached to water-backs of kitchen ranges, when no fire is in the range. It consists of a flat cylindrical gas burner of the Bunsen type, having on its upper surface numerous gas jets. One side of the burner chamber has a radial slot extending to the center to allow the burner to be

placed under the boiler, the slot encircling the central pipe usually attached to the lower head of such boilers, and the burner is fastened to the pipe by a simple form of clamp. The burner is, of course, connected suitably with the gas supply.

The report finds that while other inventors have attached closed vessels to either the circulating boiler or to its connecting pipes, these appear to have invariably required alterations of either pipes or boiler, and that Mr. Heller appears to be the first to accomplish the desired result with a device requiring no such alterations. The device is pronounced to be new, convenient and useful, and the applicant is awarded the Certificate of Merit. [*Sub-Committee*, Spencer Fullerton, Chairman; Frank P. Brown.]

Respiration Calorimeter.—A. O. Atwater and E. B. Rosa, Middletown, Conn.

ABSTRACT.—The object of this apparatus is to measure the energy of food and its metabolism in the human body—in other words, to permit of the exact study of the income and outgo of food in the animal organism and the energy generated thereby.

Reserved for publication in full.

The report recommends the award of the Elliott Cresson Medal to Professors Atwater and Rosa, and makes honorable mention of Dr. F. G. Benedict, Mr. A. W. Smith, Mr. O. S. Blakeslee, Mr. A. P. Bryant and Dr. O. T. Tower. [*Sub-Committee*, Prof. H. W. Wiley, Chairman; Prof. Geo. F. Stradling and Dr. Robt. H. Thurston.]

Pneumatic System for Preventing the Bursting of Water-Pipes by Freezing.—N. Monroe Hopkins, Washington, D. C.

ABSTRACT.—This invention involves the application to a house water-supply line of an automatically-operating air injector, situated usually where the service pipe enters the building, and which admits air to the pipes every time a faucet is opened; and in connection therewith, a series of air-domes, introduced at regular intervals along the line, wherever the pipes are exposed to liability of dangerous expansion from freezing during cold weather.

After giving the results of a series of comparative experiments made with lengths of water pipes protected with the Hopkins device, and unprotected, by exposing them to freezing by exposure in cold weather, and in an artificial freezing mixture, which resulted uniformly in the bursting of the unprotected pipes, while that provided with the Hopkins device escaped injury, the report concludes that the Hopkins device has great merit, and is of great importance. The Scott award is recommended to the inventor. [*Sub-Committee*, J. J. De Kinder, Chairman; John W. Edmundson, Frank P. Brown.]

Stereoscopic Camera.—John G. Baker, Philadelphia.

ABSTRACT.—This apparatus consists of a camera of ordinary construction and long extension, to which the inventor has added various attachments and devices to adapt it specially for the work of making stereoscopic photographs of insects and similar objects which are too large to be photographed successfully, by attaching a camera to the ordinary microscope, yet not large enough to permit of the employment of an ordinary stereoscopic camera.

The report concludes that the apparatus shows considerable ingenuity of adaptation, and that the photographs of insects obtained with the Baker camera with little trouble prove it to be admirably adapted for the special work for which it is intended. [*Sub-Committee*, F. E. Ives, Chairman; W. N. Jennings, Louis E. Levy.]

Portable Photometer.—Charles Deshler and Edwin J. McAllister, Newark, N. J.

ABSTRACT.—This instrument consists of a Bunsen or grease-spot screen, mounted above a scale which is divided to read candle-powers. At one end of the instrument is placed a standard 16 candle-power incandescent lamp, with a rheostat for controlling the voltage at the lamp terminals, and suitable connections for a voltmeter and an ammeter. At the other end is placed an oil lamp of about 32 candle-power, which is used as the working standard.

The photometer is used as follows: Having placed the standard incandescent lamp in its socket and brought it to its marked voltage, the screen is placed at 16 on the scale and the oil lamp is adjusted until the grease spots disappear or balance. The oil lamp then becomes the working or secondary standard.

The lamps to be measured are now substituted for the standard incandescent lamp, and the candle-power read directly in the usual way. The use of the oil lamp in place of an incandescent obviates the use of two voltmeters.

The lamp to be measured is supported on a spindle which is provided with mercury cups to make electrical connections to the lamp. In one form of the instrument the spindle is rotated either with a spring motor or an electric motor.

The apparatus is made in three sections, so devised as to pack together in a case, making a very portable arrangement, by which commercial or mean horizontal candle-powers may be obtained by direct reading.

The novel features of the instrument have reference to the arrangement of its parts and not to the use of the secondary standard, which has been known and used previously.

The report finds the instrument to be well adapted for its intended purpose. The inventors are awarded the Edward Longstreth Medal of Merit. [*Sub-Committee*, Arthur J. Rowland, Chairman; Geo. F. Stradling, D. Anson Partridge, Francis Head.]

The following reports passed first reading:

Electric Meter.—Wm. D. Marks, Philadelphia.
Press for Baling Cotton, etc.—Geo. A. Lowry, Chicago, Ill.
Round-Lap Baling System for Cotton.—American Cotton Co., New York.
Improvements in Steam Injectors.—Strickland L. Kneass, Philadelphia.
Rail-Joint.—Harry Vellenoweth, Philadelphia.
These were held under advisement for one month.
The following reports were made advisory and adopted:

Electrical Switch.—Paul A. Medary, Cynwyd, Penna.
Hydraulic Air-Compressor.—Albert A. E. Sterzing, New York.
Improvement in Valves.—Joseph F. Batchelor, Philadelphia.

W.

SECTIONS.

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—The first stated meeting of the Section was held on Tuesday, March 6th. Dr. Henry Leffmann in the chair.

Present, 55 members and visitors.

The questions of adopting a code of regulations and nominations for officers were referred to the Executive Committee, with instructions to report at the next stated meeting.

Dr. Leffmann addressed the meeting on the "Theories of Photographic Development." He pointed out that most of the modern developers in photography are benzene derivatives, and partake of the character of that substance in being rather difficult of complete oxidation, and hence exercised restricted reducing action. The localization of the deposited silver upon the impressed portions of the latent image may be due to the difference in electric potential owing to the disturbance in the homogeneity of the film. This condition naturally establishes a polarity which would cause a selective deposition of the silver.

Mr. F. E. Ives followed with a description of the practical remedies for the difficulties encountered from under- and over-exposure.

Mr. John G. Baker exhibited and described an ingenious apparatus for determining the time of shutter exposure.

A general discussion followed on methods of preparing lantern slides.

F. W. SAWYER,
Secretary.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, Thursday, March 8th. Mr. Wilfred Lewis in the chair.

Present, 32 members and visitors.

The following officers were elected for the current year: President, John F. Rowland, Jr.; Vice-Presidents, Arthur Falkenau, Spencer Fullerton; Secretary, Daniel Epplesheimer; Conservator, Dr. Wahl.

The subject for discussion was "Portable Machine Tools," and was opened by Horace G. Hoadley, of Waterbury, Conn. Mr. Hoadley exhibited and described several improved forms of portable tools made by the Waterbury Tool Company, notably an improved form of ratchet drill for drilling in close places where no other ratchet can be used for lack of room for the movement of the handle. He also showed and described a portable tool for screwing up and unscrewing nuts in similar situations.

Mr. James Christie spoke of the great utility of portable pneumatic tools in modern shop practice and of the great development of the manufacture of tools of this class. He gave some account of his experience with electrically-driven tools for similar uses, and of the difficulties he had encountered in the attempt to make serviceable tools of that class.

Mr. W. R. Webster gave a brief account of his experience in attempting to devise a practical pneumatic riveter.

Mr. J. Logan Fitts and Mr. Spencer Fullerton spoke in general terms of the relative importance of the several classes of portable tools in erection and repair work. W.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, held Wednesday, March 14th. Mr. Joseph Richards in the chair.

Present, 26 members and visitors.

The evening was devoted to the discussion of the paper read last spring by Mr. Paul Kreuzpointner, of Altoona, Pa., entitled "Riddles Wrought In Iron and Steel," in which the author set forth a number of contradictory and apparently inexplicable anomalies encountered in the manipulation of these metals.

The discussion was opened by Mr. Wm. R. Webster, who urged, in answer to some of the difficulties raised by the author in connection with the heat treatment of steel, that they are readily comprehensible and manageable when all the data are known.

Mr. A. E. Outerbridge, Jr., followed with some remarks upon the heat treatment of cast iron, in the course of which he made the announcement that, contrary to the usually accepted opinion, this alloy is materially weakened by annealing, and can be hardened, like steel, by rapid cooling. The weakening the speaker attributes to the change of the carbon of the alloy from the combined to the graphitic state. His experiments were made on soft gray iron.

Messrs. James Christie, Asa W. Whitney, Francis Schumann and the Chairman joined in the discussion, and a number of contributions were received by letter. The paper and discussion will be published in full in the *Journal*.

G. H. CLAMER,
Secretary.

CHEMICAL SECTION, ELECTRICAL SECTION, PHYSICAL AND ASTRONOMICAL SECTION.—A joint meeting of the three sections was held on Tuesday evening, March 20th, at 8 o'clock.

Present, 64 members and visitors.

Dr. W. J. Williams in the chair.

The meeting was devoted to the presentation of a paper entitled "Experimental Studies of the Acetylene Flame," by Prof. Edward L. Nichols, Cornell University.

Professor Nichols considered the acetylene flame with reference to its use in the physical laboratory, rather than from the industrial side. He referred to the influence of age and of the mode of production of the gas on the brightness and color of the flame; to the properties of the flames of mixtures of acetylene and hydrogen; to the structure of the flame with reference to its use in photometric work; to its color, radiant efficiency, etc., etc.

The paper was concluded by a consideration of the merits and demerits of acetylene as a standard in spectro-photometry and in ordinary photometric operations, and the precautions which it will be necessary to take in the establishment of a reproducible primary standard. (This paper will shortly be published in full.) W.